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Topics of the Month

Exports of pressure vessels to Canada

A SECTION to deal with the approval in the U.K. of air receivers, boilers and pressure vessels intended for export to Canada has been set up by the British Standards Institution. The staff of this section are familiar with conditions in the engineering industry in Canada and will provide manufacturers with information and help.

This follows the recent acceptance of British pressure vessels by the Canadian Standards Association, as reported in the September issue of CHEMICAL & PROCESS ENGINEERING (p. 301). It was towards the end of last year that the B.S.I., with the object of helping British makers in exporting pressure vessels to Canada, approached the Chief of the Boiler Inspection Department of Quebec. After discussions, arrangements were made for suitably certificated British pressure vessels to be accepted in the Province of Quebec. By agreement with the C.S.A. Committee on Canadian Boiler Regulations these arrangements have now been extended to all Canadian provinces, whose chief inspectors have agreed to accept equipment manufactured in the U.K., provided that the necessary registration with Canada has been effected and that the equipment has been constructed and inspected in accordance with Canadian requirements.

There is already a B.S.I./C.S.A. Approvals Agency for electrical equipment and the new B.S.I. section will be associated with this. This arrangement should simplify matters for makers of equipment such as electrode boilers and electrically-operated pressure-vessel accessories, which have to comply not only with the Canadian Electrical Code but with Canadian pressure-vessel standards as well.

British technology for India and Burma

EXPERIENCE and technology, let us call it know-how, is becoming an increasingly important export commodity. Under-developed countries are no longer content to buy the goods of the Western World, they want to make the goods themselves. So the West must be prepared to sell know-how. The chemical and chemical engineering industries have not been slow in responding to this change in the pattern of export demand and already some important post-war chemical projects have been carried out abroad.

Now comes news of two new projects for which the independent governments of two countries which were formerly part of the British Empire have turned to British firms.

The Indian Government has long wanted to establish a blasting explosives industry capable of meeting the country's whole requirements. These needs have increased owing to the development of mining, and to the large public expenditure on water, power and irrigation works, and on road building. The government has accordingly made an agreement with Imperial Chemical Industries Ltd. under which a new company, Indian Explosives Ltd., will be formed to make commercial blasting explosives. Initially Rs. 2 crores (£1½ million) of capital will be issued, of which 80% will be subscribed by I.C.I. and 20% by the Government of India.

A site has been selected for the factory near the Bihar coalfield, the coal-mining industry being the principal consumer of industrial explosives in India. I.C.I., through their Nobel Division, will be responsible for planning the layout

of the works and providing designs for the plant and equipment, and will be responsible for its erection and setting to work. They will also provide all the technical knowledge required to operate the factory, information on research and, initially, all management staff required and a number of key workers. The factory will give direct employment to about 400 persons in all. I.C.I. have undertaken to train Indians to take over responsible positions. The establishment of this company adds a new manufacturing activity to those which I.C.I. undertake in India through their Indian subsidiary, Alkali & Chemical Corporation of India Ltd. (which manufactures heavy chemicals and paints) and I.C.I. (India) Ltd. (which formulates dyestuffs and manufactures plastic film).

The second project is in India's neighbour, Burma. There, on an 80-acre site near Rangoon, a pharmaceutical industry is to be set up for the Burmese Government by Evans Medical Supplies Ltd. The initial expenditure, about £1 million, is to be made entirely by the Burmese Government. Unlike the I.C.I. project, no British capital whatsoever will be invested. Evans have been engaged to supply know-how, to supervise the building of the factory, to act as purchasing agents, to provide staff and to manage the factory. The contract, which was obtained by Evans in the face of strong competition from other companies, British and foreign, will run for an initial period of seven years. During this time it is estimated that it will be worth several million pounds, allowing for the payment of British staff, professional fees, Evans's charges, British machinery and raw materials.

Evans hope to have the factory working by the end of next year. At first it will be used for simple operations such as the dispensing and repackaging of imported bulk supplies of finished medicines. Later, manufacture will be undertaken of a wide range of pharmaceuticals.

Coal gasification conference

WHILE fuel technologists seek more economic use of coal as a fuel, chemical engineers are trying to improve processes in which it is used as a raw material for chemical synthesis. Coal can be used for either of these purposes by gasification. The report of a European mission which went to the U.S.A. to study this subject was summarised in CHEMICAL & PROCESS ENGINEERING, September. One of the conclusions reached in this report was that ' the development of a universal and economically efficient gas producer will be attained all the sooner if the partial solutions arrived at in the U.S.A. are more rapidly brought to the notice of European research workers, and *vice versa*.' It must be gratifying, to the authors of the report, therefore, to learn that technicians and research workers from all over the world are invited to an International Conference on the Complete Gasification of Mined Coal, to be held at Liège, Belgium from May 3 to 8, 1954.

The conference, organised by the Belgian Institut National de l'Industrie Charbonniere (Inichar), will take place during the annual international fair for the mining, metallurgical, mechanical engineering and electrical industries. An important part of the fair will be devoted to gasification. The meetings will be followed by visits to the principal gasification plants of Western Europe. Full information is available from Inichar, Boulevard Frère-Orban 7, Liège, Belgium.

Complete gasification has already been the subject of various international studies. Besides the O.E.E.C. mission, already referred to, there has been the New York symposium held by the U.S. Bureau of Mines in February 1952, and the Essen meeting of November 1951 organised by the Deutsche Kohlenbergbau-Leitung.

Interest in gasification is not confined to those countries which have no natural gas resources. Countries rich in both coal and natural gas, such as the U.S., are studying the problems with equal keenness. This is no way paradoxical; in comparison with the coal reserves of these countries, natural gas reserves are small and their exhaustion is within sight. The very prosperity of the industries utilising natural gas makes it necessary to develop a replacement.

Filtration-extraction of oilseeds

A NEW process of direct solvent extraction for oilseeds, called filtration-extraction, has gone into commercial use in a mill in Mississippi, U.S.A. This mill will convert from hydraulic pressing to filtration-extraction and will process both cotton seed and soya beans. Rated daily capacities with cotton seed will be 150 tons and with soya beans 75 tons. This mill is the first to install a complete solvent-extraction system based on filtration-extraction.

The new process is claimed to be readily adaptable for quick conversion from one oilseed material to another, and no prepressing is required. Filtration-extraction may make it possible for smaller mills to apply solvent extraction because installations appear to be feasible with rated daily capacities as low as 75 tons for cotton seed. This capacity is in contrast to the range of 150 to 400 tons and more daily usually found in other solvent plants for cotton seed.

Filtration-extraction for oilseeds was developed through the pilot-plant stage at the Southern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry, U.S. Department of Agriculture. Sixty-four pilot-plant runs, using mainly cotton seed, rice bran and soya beans, demonstrated the efficiency and versatility of the process and the comparable quality of filtration-extracted oil and meal with the products of conventional processes. On the basis of pilot-plant results, three United States firms have designed and advertised plants for sale and four others have obtained licences from the Department of Agriculture to use the process (Bureau patent is pending).

Filtration-extraction departs from conventional methods in the preparation of the material after delintering and dehulling, as well as in the extraction phase. The rolled flakes are cooked, and the cooked product is cooled and ' crisped ' by evaporation. Practically all of the preparation equipment used by hydraulic mills is used in filtration-extraction, with only minor changes.

After the preparation of the meats, the oil is brought into solution in a mixing vessel, and the oil solution (miscella) is removed in a standard continuous, horizontal, vacuum filter. These two units replace the extractor and the presses of other solvent methods. Properly prepared material is soaked in the mixing vessel in contact with miscella for 15 to 25 min., to dissolve the oil. Then the slurry of meal in concentrated miscella (about 30% oil) is fed to the filter. There the miscella is filtered off and the meal is counter-currently washed and successively drained three times—in less than 3 min. The residual oil in the extracted meal (marc) is 1% or less.

While the use of a horizontal vacuum filter to conduct counter-current washing is not a radical application, the pre-mixing or slurrying step in a separate vessel followed by counter-currently washing on the filter, and the method of

preparation which makes these combined steps possible, are recognised as an innovation in the technology of oilseeds extraction.

The vacuum drainage before and after each wash on the filter results in a lower solvent content of both extracted meal and final miscella, and allows a lower solvent-to-meats ratio, lower steam costs and the use of smaller equipment than with conventional processes. These features result also in a high production capacity for a small-sized filter unit. For example, the 3-ft.-diameter pilot-plant filter has been operated at a capacity up to 6 tons of cotton seed per day per sq. ft. of filter screen, amounting to about 21 tons/day. For a capacity of 3 tons/day/sq.ft. of filter screen, the filter operates with a 2-in. cake, at a pan speed of 2.5 to 3.5 min. per revolution under a vacuum of 1 to 6 in. of mercury. The filter can be placed on stream in minutes, and many operating variables can be controlled automatically, resulting in low labour costs, low down-time and uniformity of products. All advantages are realised without impairing production of marketable oil and meal.

The Southern Regional Research Laboratory, in co-operation with oilseed processors, is continuing pilot-plant operations with various other oil-bearing materials, to understand better the principles and variables involved in the preparation and extraction phases, to determine the different conditions required for the different materials and to improve the general processes and product quality.

The magnesium story

YET another change in the history of magnesium in the United Kingdom comes on January 1 when the Ministry of Materials will hand back to private interests the importation and selling of the metal. This second change over will be keenly followed by those in the trade, particularly since British manufacturers have to compete with imports from Canada and Norway with their advantages in electrical power. There is a 10% tariff on all imports except those from Canada or the Commonwealth, yet natural sources of power mean so much to magnesium production.

The history of magnesium in Britain has been a fluctuating one, especially with the war years producing a peak out of all proportion to previous developments. While the very first opening to the magnesium story was very much a British affair, with Epsom salt being ' British salt ' or ' English salt ' when discovered on Epsom Common, the metal itself had only a slow beginning in this country. Davy first prepared magnesium in 1808, not by electrolysis as with his other active metals, but by thermal reduction with potassium. The story then switched to France, with Bussy succeeding in reducing the anhydrous chloride also with potassium; this after having provided a basis of modern industry with his anhydrous chloride preparation from the reaction of magnesia with carbon and chlorine. Later, Deville, in France, fresh from his aluminium-making using sodium reduction, included magnesium prepared by such a reduction process. Although the versatile Bunsen in 1852 scored a point for his country with the first electrolysis of molten magnesium chloride, by 1857 France was in the picture again with the first commercial production of magnesium mainly required for flashlight photography. But by 1864, English interests were roused sufficiently to start small-scale production, again chiefly for flashlight work and pyrotechnics, with a small amount beginning to be in demand for deoxidation in metallurgy. This 1864 project, pioneered by the eminent metallurgists Johnson and Matthey, opened at Salford and then transferred to Patricroft, an opening to a British industry which was to be centred in the Manchester area as regards production of the metal itself. The whole industry was a small affair and remained so in comparison with wide development in Germany and until war-time demands brought a large British production (Germany applied Bunsen's academic studies on a large scale and was well in the leading position right up to 1939). Yet during these last 12 years our home industry, a century and a half after Davy conjured the first bead of metal, has seen considerable development with the war-time Murex process using calcium carbide for reduction, the Magnesium Metal Corporation's adoption of the Hansgirg carbothermic process at Swansea, the Lancashire Metal Subliming Corporation's activities in 1943-44 and Magnesium Elektron's large-scale production at Clifton Junction. British magnesium from sea water seems but a just reward for a nation surrounded by the sea.

Iraq plans chemical industries

IRAQ is likely to develop into a substantial market for British chemical plant and other capital equipment. As is well known, Iraq's prosperity is based on petroleum. This year the revenue from the oil industry is expected to rise to 50 million dinars, equivalent to £50 million, and if plans are fulfilled it will probably reach 60 million dinars p.a. The vast quantities of natural gas being released at Kirkuk and Zubair in the course of oil industry development are being considered as the basis of chemical industries producing sulphate of ammonia, cement and sulphur. A detailed investigation of natural gas resources and their utilisation has been prepared by consulting engineers and is now being studied by the Iraq Government.

Present industrial plans made by the government include the erection of a 1-million-ton-p.a. oil refinery in the Baghdad district, now in course of construction, and the establishment of a 60,000-ton-p.a. bitumen plant at Gayara. The government is also enquiring into the possibilities of developing the salt industry and of introducing sugar-beet cultivation to enable sugar factories to be erected in the north. Private enterprise is responsible for the erection of a new cement factory at Mosul, the expansion of the vegetable oil crushing and refining industry, the manufacture of soap and other related projects. The manufacture of caustic soda by the electrolysis of salt is also under investigation, although Iraq's present demand for this chemical would hardly seem to be enough to absorb the output of a plant of the minimum economic size.

Incentive scheme for plant maintenance men

AN incentive scheme for maintenance men, based on work study, at the Ministry of Materials fertiliser factory, operated by I.C.I., at Prudhoe, Northumberland, has proved so successful that after the trial period on the ammonium sulphate plant was completed workers in other departments were requesting its wider application.

Formerly, 23 tradesmen were employed in the maintenance squad on this plant, but now only 10 are needed, including the estimator responsible for assessing allowed times for each job. They earn an average bonus of about £2 10s. each for a full week.

The incentive scheme, as explained in *Target*, is based on allowed times for each job. The estimator is himself a tradesman, chosen from the maintenance gang and sent to I.C.I. Divisional Headquarters at Billingham for training,

which includes instruction in method study, time study and rating, as well as the technique of analytical estimating.

In analytical estimating the emphasis is first of all on method, since no attempt can be made to estimate the time a job should take without a clear understanding as to what the job involves and how it is to be done. This agreed, the estimator sets out a detailed breakdown of the job into short elements. To each element he assigns a time, drawing on his experience as a tradesman and training as an estimator, and referring wherever possible to standard data.

To the total of the element times the estimator adds a rest allowance appropriate to the type of job. Allowances vary from 12½% for normal fitting work to as much as 50% for work involving the use of respirators and cumbersome protective clothing. A further allowance is made to cover walking between jobs and washing at the end of the day.

Each tradesman is given a card with a brief description of the job and the time allowed for it. On completing the job he returns this card to his supervisor.

His bonus is calculated weekly from the total allowed time for all jobs he has done and the time taken to do them. The time taken is the time shown on his clock card for the week, less any delays or time spent on non-bonus jobs.

The responsibility is again on the tradesman to inform his supervisor whenever he has finished a job or is held up for any reason; failure to do so will affect his bonus earnings. The supervisor is keenly interested in eliminating all unnecessary delays, because the percentage time on bonus of the gang is one of the factors that determine his own bonus.

The bonus calculations are based on:

$$\text{Performance} = \frac{\text{Total time allowed}}{\text{Total time taken}} \times 100$$

Each performance corresponds to a bonus rate per hour, payment starting at 75. All estimates are made out so that the average tradesman working at a brisk, workmanlike pace should complete the job in three-quarters of the time allowed. At this performance, *i.e.* 133, he will earn a bonus equal to one-third of his full tradesman's hourly rate. To discourage any tendency to relax standards of workmanship, a maximum earning rate is set at time and a half, and this is paid at a performance of 200. Only good work is paid for, and jobs must be carried out in a safe, satisfactory and workmanlike manner to rank for bonus payment.

More than 15,000 jobs have been done on bonus since the start of the scheme, and no dispute has yet arisen that has not been settled at plant level.

Chilean nitrate industry's problems

THE output of the nitrate industry in Chile has been declining steadily since 1948. Production then was 1.8 million metric tons. Last year it fell to 1.4 m. tons. The target this year was set at 1.65 m. tons, but it is doubtful if it will be reached, in view of the 57-day strike which paralysed production at the Anglo-Lautaro works, the biggest in the industry, normally reasponsible for 62% of total output. However, workers' unrest is but one of the industry's problems. As reported in our September issue (p. 300), the industry's exports to South American countries are threatened by these countries' plans to build synthetic nitrogen plants. Colombia recently announced its intention of building a nitrogen plant and similar probjects have been planned by Brazil and Argentina.

The Chilean industry's answer has been to take the first steps in developing a solar evaporation process to make use of low-grade ores and take advantage of washings left after processing of the ore. This will make possible fuller exploitation of the nitrate reserves and permit production of not only the common sodium and potassium nitrates but also other salts. This would broaden the scope of the Chilean heavy chemical industry.

New raw materials for paper

A RECENT publication by U.N.E.S.C.O. and F.A.O., 'Paper for Printing,' surveys world resources for the future, and logically reaches the conclusion that paper based on wood pulp will always be in short supply. As the world becomes more literate, demand from all countries must increase, yet even now it is only the dollar countries who can use newsprint without imposed or voluntary restrictions. The spruce and fir forests of Canada, Scandinavia and Russia are renewable, so fundamentally the source of paper is not a diminishing asset; however, supplies are renewable only at Nature's rate of replenishment. Newsprint manufacturers have not been enthusiastic about expanding their plants, as they cannot feel confident that wood pulp output can sustain a significantly increased manufacture of newsprint. Every factor seems fairly rigid except demand.

The escape from the tightening circle is to use other sources of fibres. Bagasse, the waste residue after extracting sugar from canes, is now being used to make high-quality papers in several factories. Bamboo is used extensively in India. Hard wood from tropical forests may be capable of being used—the French are busily developing pulps from African forests. The large-scale utilisation of these alternative materials, strongly pressed in the U.N.E.S.C.O.-F.A.O. book, would have a sizeable impact upon the chemical industry. For the pulps that can be made from them are chemical pulps. Soft wood pulp, as used to the extent of at least 80% in newsprint manufacture today, is mechanical pulp, 'machine-minced,' not 'chemically-cooked.' What is most urgently needed is a process by which chemical pulps can be more heavily used in making newsprint, say, up to 75 or even 100%. Recently it has been claimed in America that a fairly good newsprint has been made at low cost from bagasse pulp; it remains for time to show how sound the claim is. Newsprint must be cheap and have great mechanical strength. Durability and high-quality surface are less vital requirements. Hence the predominance of mechanical pulp—it costs about half the price of chemical pulp and it brings greater fibrous strength. But the technological picture is far from static. Good chemical pulps from bagasse, bamboo or hard woods (or from all three) and a newsprint process based on this type of pulp would lead to pulp or paper-making industries in many of the underdeveloped countries whose rising paper demand cannot possibly be met. To some extent this is now beginning. Mauritius is setting up a bagasse pulp industry and can export pulp at half the cost of Scandinavian pulp. It is a most probable world development and in time it may well revolutionise a somewhat conservative industry.

Apart from the direct demand for chemicals for the two major pulp processes—sulphite, and sulphate plus soda—that these new paper industries would bring, the large-scale production of new types of pulp could have a considerable influence upon the chemical industry's own use of cellulose. Rising demands of non-paper kinds for wood pulp supplies are aggravating the newsprint situation. A wider variety of cellulose-fibre pulps may prove of benefit to the chemical industry. Cellulose fibre processes may prove more flexible, technologically, than other paper-making processes.

Recent Advances in MILK PROCESSING PLANT

By J. E. F. Renton, B.Sc., A.R.I.C.

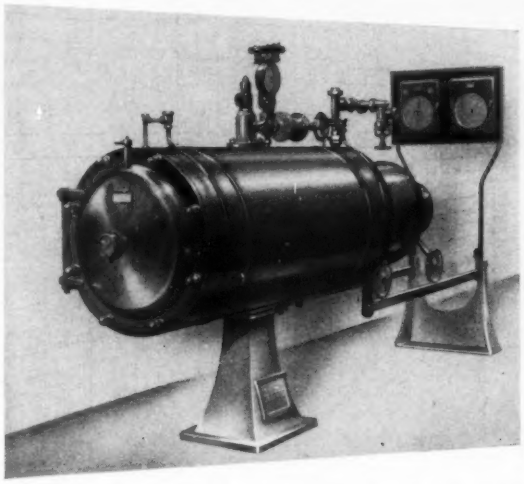
(George Scott and Son (London) Ltd.)

The principles of plant for milk processing have been established for many years, so that advances tend to be concerned more with changes in processing techniques rather than with the re-design of fundamentals. In this paper* the author deals with such advances in heating, evaporating and drying plant for milk products. The demand for stricter process control and the increasing costs of production have been two factors influencing design and construction. Although the industry generally is a conservative one, circumstances have forced it to accept changes. Consequently there is now much wider use of continuously operating plant, automatic control, fuel economy devices such as double-effect and forced-circulation evaporators, and chemical cleaning.

MAINTENANCE of absolute cleanliness is, of course, essential when handling any food products and, therefore, in recent years manufacturers of milk processing plant have given considerable attention to facilities for maintaining plant in first-class condition at all times. Greater attention has been paid to details of design and quite elaborate auxiliaries have been used. Simplification of design to reduce the time needed for cleaning has been another objective made necessary by the increase in the cost of labour.

Probably the most important change in the last few years has been the almost complete standardisation of stainless steel for all processing equipment. It has been found that many of the copper and alloyed metals cause off-flavours in milk products and inferior shelf life. Aluminium, whilst otherwise satisfactory, is somewhat soft and very susceptible to caustic detergents. Glass and glass-enamelled steel are also used to a certain extent, but, of course, they are more vulnerable to damage than other plant.

Up to the present, cleaning has required daily dismantling of all parts of equipment such as heat exchangers, pipelines, etc. This raised the hazard of broken joints and the possible leakage of milk and air into vacuum systems. These problems have been solved to a great extent by the increased use of chemical cleaning. Although this has not advanced greatly in Great Britain, in America and on the Continent the use of nitric acid with a following wash of caustic soda and thorough rinsing is becoming established. It has the great advantage of permitting the use of many more permanent joints with less daily mechanical hazard. Deterrents to the use of chemical cleaning in Britain include the somewhat conservative attitude of users and the reluctance of the stainless-steel manufacturers to recommend lower grades of stainless steel that are otherwise perfectly satisfactory for fabrication and handling. However, in spite of these obstacles, there is a definite trend towards chemical cleaning and, provided reasonable control is exercised in the cleaning operation, this trend should gather momentum.



Forced-circulation milk heater capable of preheating 2,000 gal./hr. of raw milk from 40 to 250° F. The milk is maintained in constant circulation through the tubes at a speed of 6 to 8 ft./sec.

Glass pipelines are becoming more common in milk pasteurising plants, but they are not being used to any extent for process plant, possibly owing to the high temperatures involved and the need for the occasional breakdown of pipelines. Another point, of course, is that, with the very high cost of replacements, users probably hesitate to scrap what is otherwise perfectly good equipment.

Evaporated milk

Dealing very generally with the manufacture of evaporated milk as distinct from the sweetened product, the stages of manufacture consist of forewarming, concentration, homogenisation, cooling, canning and sterilisation.

Forewarming for evaporated milk was formerly carried out at relatively low temperatures, but it has been found that more satisfactory results are obtained by short-time high-temperature heating, and temperatures up to 250°F. are quite common. These high temperatures, however, have necessitated the abandonment of the old centrifugal pasteuriser in favour of high-velocity heaters of the tube, plate or forced-circulation type.

In all high-temperature units the milk must be maintained under pressure to prevent gas formation and boiling and, in the case of tubular heaters, it is passed through several sections of tube which in some cases are fitted with core tubes to increase velocity. Even with these arrangements, however, velocity through the tubes, without the use of small-bore tubes and high power, is relatively slow and in the order of 1 to 2 ft./sec.

The plate heat exchanger is certainly a vast improvement, consisting as it does of a number of thin, indented, stainless-steel plates somewhat in the form of a filter press. Considerable facilities exist here for heat exchange by the use of hot condensate where available, particularly where this is not required for other purposes or where it may be slightly contaminated. This type of heater is particularly easy to open up for cleaning and its basic capacity may be adjusted quite easily by adding or removing plates.

Another type of heater is the forced-circulation tubular unit, in which the milk is maintained in constant circulation at a speed through the tubes of 6 to 8 ft./sec., heating being by steam controlled from the outlet milk temperature. The cold milk is delivered under pressure by a pump and mixes with the hot milk already in circulation, the circulation being of the

*Presented at the Chemical Engineering Conference, Olympia, London, September 1953. Sponsored by the Institution of Chemical Engineers and the Chemical Engineering Group, S.C.I.

order of about 30 to 40 times that of the throughput. A quantity of milk equivalent to the input is bled out from the hottest portion of the heater and goes to process. It has been found in practice in heaters of this type, running for 20 hr./day at 240°F., that at the end of the day they are relatively free from milk scale.

For concentration the coil pan is now outmoded, being replaced by continuous tubular units which may be of single- or multiple-effect types. Steam economy has removed the previous British prejudices to multiple-effect working and a number of high-velocity tubular units of either upward- or downward-pass type are now being utilised.

A further type which has found favour is the forced-circulation unit combined with thermo-compression. The forced circulation maintains the milk under circulation at a high rate and thermo-compression can give economies equivalent to double-effect working whilst avoiding the relatively high temperature of a first effect and at the same time confining the cleaning, which is inevitable, to one pan.

Considerable attention has also been given to efficient entrainment separators, particularly with the modern high-velocity evaporators.

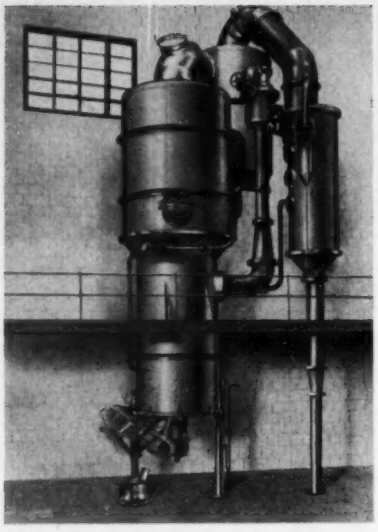
It is not normally possible to employ the highly efficient type of separator used for trade liquors, owing to cleaning difficulties, but considerable success has been obtained with internal separators of the turbine ring and umbrella type. These have the effect of speeding up the vapour passes so that entrained droplets are thrown out by centrifugal force.

External separators are mostly of the centrifugal type in which the vapour enters tangentially, the milk droplets being forced to the outer periphery. These units may be arranged to pass vapour either up or down to a condenser according to the layout.

Apart from the prevention of milk losses, entrainment separation becomes increasingly necessary with multiple-effect units and thermo-compression units.

In America it is reported that work is being carried out on triple-effect operation, but automatic control is essential with these larger multiple-effect plants. Automatic control of evaporators consists essentially of steam control to the first effect, level controls for each pan, absolute pressure control operating on the cooling water and final density and, of these, the latter is the most difficult to achieve. However, considerable success is now being obtained, working on certain types of purging unit for both level and density.

On the question of control gear, an interesting piece of auxiliary equipment has been developed mainly in connection with thermo-compression evaporators and double-effect pans. In these, as will be understood, the vapour from the boiling milk is entrained in part by a steam jet and returns to the calandria as heating

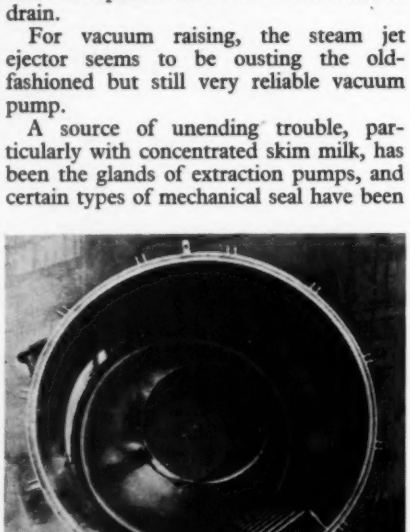


Forced-circulation milk-condensing plant with a capacity of 1,000 gal./hr. This type of equipment can be used for either batch or continuous working and is suitable for the production of evaporated and condensed milk or whey and for pre-condensing before spray drying.

steam or passes direct to second effect. Despite the most efficient entrainment separators, there still exists the chance of a boil over owing to accidental causes and this would contaminate the condensed steam which might otherwise be used for boiler feed. This difficulty has now been largely overcome by the use of a photo-electric device for the selective acceptance or rejection of condensate. These units are extremely sensitive and a slight reduction in transparency causes a flow diversion valve to operate and divert the water to drain.

For vacuum raising, the steam jet ejector seems to be ousting the old-fashioned but still very reliable vacuum pump.

A source of unending trouble, particularly with concentrated skim milk, has been the glands of extraction pumps, and certain types of mechanical seal have been found very efficient and free from failure.



Internal view of vertical-type entrainment separator with cover removed and showing access to interior.

In the sterilisation of the finished evaporated milk in the can the continuous steriliser is now taking the place of the batch-type rotating-basket unit in the larger plants, although this still has its application for small outputs. A continuous steriliser consists essentially of three compartments, one bringing up the temperature, one carrying out the sterilisation and one partially cooling. The path of the cans through the steriliser is usually spiral, thus giving automatic rotation to the cans to prevent sedimentation and burning. Adjustments can be made in processing time and temperatures according to seasonal variation in the product. Capacities of 120 cans/min. are quite standard and machines are available, at least in America, for larger throughputs. These units lend themselves particularly to automatic pressure and temperature control both on the heating and cooling sections.

Sweetened condensed milk

With sweetened condensed milk there is no final sterilisation of the product by heat; the added sugar acts as a preservative. Particular attention is now given to quality of sugar and, after suitable storage, the general practice is to dissolve in water so that the syrup itself can thereafter be sterilised and filtered.

The remarks previously made regarding forewarming and concentration of evaporated milk apply equally well in the main to condensed milk. However, very considerable care must be taken with the temperature of forewarming, as this has a bearing on the subsequent shelf life of the product, particularly for export to hot countries.

In Britain, condensed milk is usually made by the batch process, possibly because of the difficulty of equalising proportions of milk and sugar and also because it is possible to strike the batch at the exact end point required.

However, work is being carried out, particularly by Continental manufacturers, on continuous processing, but it appears too early to give any definite results. It is quite possible that, with the use of the modern refractometer combined with automatic control, it may be possible to obtain a finished material conforming exactly to requirements and permit work on a continuous system. The refractometer can be applied direct. It will be appreciated that it is not easy to standardise a sweetened product after manufacture.

The pan having been struck, the next operation is the cooling, which is extremely important for this type of product. In fact, sweetened condensed milk is a partial suspension of lactose crystals and slow cooling results in large crystal formation and a 'sandy' product.

In general, the jacketed shell or the tubular coolers are used. The coolant is either chilled water or brine.

In the tubular type the process becomes virtually continuous, although a holding tank is necessary to feed the cooler. High pressures are set up in these coolers and this pressure appears to scour the cooling surfaces.

Recently, however, there has been renewed interest in vacuum cooling, although this is not entirely new. In this process the whole batch of milk is transferred into a single-shell vessel arranged for intensive agitation. The cooling takes place by the application of vacuum which cools the milk by evaporation of the heat in the milk itself. On reaching seeding temperature the vacuum is held, seeding taking place usually by the introduction of finely ground lactose, and forced crystallisation is carried out for 30 to 45 min. Thereafter the whole batch is cooled down to about 70°F. by a further increase in vacuum.

The system appears to have the advantage of extreme flexibility and certainly eliminates any build up of super-cooled milk on the walls and at the same time gives a de-aerated product.

Vacuum may be produced by conventional means such as steam jet ejectors or a combination of brine and water-cooled surface condensers with steam jets or dry vacuum pumps.

It must be understood, of course, that some adjustment of the striking point of the pan is necessary to allow for the water evaporated during cooling. The process lends itself particularly well to automatic control by the use of a 'cam form controller.'

An accompanying photograph shows a typical photo micrograph of a sweetened skim product and shows the uniformity of crystal formation. It is usually considered that a crystal size of 8 to 10 millimicrons is desirable.

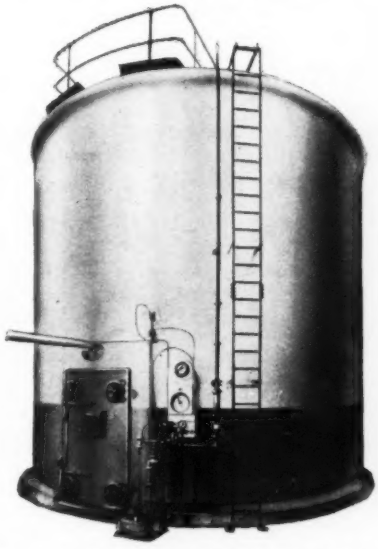
A photo micrograph of a sweetened skim product, showing uniformity of crystal formation. Magnification 250.

Dried milk

There are three main drying processes which appear to be suitable for the drying of milk. The most recent of these is freeze drying, following the successful work which has been carried out, particularly in the United States, on the freeze drying of fruit juices. In the process the milk is frozen and the water separated by either centrifuging the mixture of ice crystals and milk solids or by evaporating the water from the frozen mass by sublimation under a very high vacuum. Both of these freeze-drying processes are still very much in the experimental stage as far as milk is concerned and possibly the major obstacles at present are the capital and operating costs. In some ways it appears that, as heat seems necessary for the proper sterilisation of the milk, it is logical to continue heating and drying by the application of heat rather than to go through the freezing process. It is, of course, necessary to carry out the further processing of evaporation and drying in a minimum time, but this can be readily dealt with by modern quick-pass evaporating units and spray driers.

Milk drying by the more usual principles of heat application can be divided into drum drying and spray drying.

In the drum drier milk is dried as a thin film on the surface of a slowly rotating, steam-heated cylindrical drum. This, of course, is a well-established system and, although it does not produce a powder of such a high solubility as a spray drier, it has the advantage that capital cost is relatively low and in this way has considerable applications for relatively small throughputs and is useful for the handling of surplus milk. Roller driers may be of the single-drum or double-drum type, the milk being fed either by means of a doctor roll or by direct spraying into the 'V' of the double-drum drier.



Spray-drying unit to handle 1,500 gal./hr. of raw milk after pre-condensing to 45% solids. The product has a solubility of 99.7 to 99.8% in cold water.

Recent advances in the chromium plating of large drums are of particular interest, because of the greater facilities for the removal of the milk film from the hot surface and the consequent reduction of the risk of burnt particles.

For the sake of steam economy, preconcentration to 25 to 30% solids is often carried out and this at the same time increases the throughput from a given roller unit.

Work has also been carried out on certain types of air-circulating drum driers, characterised in general by the countercurrent application of an air stream over the surface of the drum, which has the effect of increasing evaporation and reducing the surface temperature of the milk. Remarkably high solubility figures have been attained by this system, but, in Britain at least, progress has been seriously delayed by the difficulty of chromium plating rolls of a sufficiently large size to offset the relatively high cost of this type of unit. It has been found that chromium plating does assist very materially in this process. There are indications, however, that British manufacturers will shortly be in a position to deal with very much larger rolls, when it is expected that further progress can be made.

It has always been claimed that a drum-dried powder has a more satisfactory shelf life that a spray-dried powder, and this was certainly a perfectly valid argument up to a few years ago.

However, recent work has shown that short-time high-temperature preheating of the milk has considerable improved the keeping qualities of spray-dried powders. The spray drier, of course, has the great advantage of being able to deal with large quantities of milk and, despite the high capital cost, can be made a satisfactory economic proposition.

One of the great advantages of spray-dried powder is its superior solubility, most spray-dried powders being almost completely soluble in cold water, whereas roller powders have a solubility in the order of 75 to 80%.

Vacuum roller powders have a solubility approaching that of spray-dried powders, but little use appears to be made of the vacuum roller drier, possibly owing to the difficulties of maintenance and cleaning.

Spray drying is a more costly process than drum drying as it calls for perhaps twice as much steam per lb. of evaporation and, for this reason, it is normal practice to pre-concentrate the milk in vacuum pans to the order of 45 to 50% solids. Considerable economy can be obtained in the pre-concentration by the use of multiple effect, thermo-compression, etc.

Very generally spray drying plants may be divided into two types, one in which the spray is formed by direct pressure through a fine nozzle, and the second in which the spray is produced in a rotary

atomiser. The latter type is probably by far the more generally used and, with the general tendency at the present time to increase the total solids of the feed as far as possible, this type of atomiser certainly has advantages.

Drying chambers in general are cylindrical with either conical or flat bottoms, the latter type being fitted with scraper gear to remove the milk powder. The general tendency now is to employ stainless-steel shells which are usually fully welded on site.

The method of driving rotary atomisers has received considerable attention, as the atomiser is obviously an extremely important unit. In some cases geared units are employed and considerable attention has been given to the design of the gearing. There are now on the market several types of direct electrically-driven units which appear to have certain advantages. These are simple rotor/stator units with the rotor mounted direct on the atomiser shaft, the necessary speed being obtained by frequency changers in the electrical circuit.

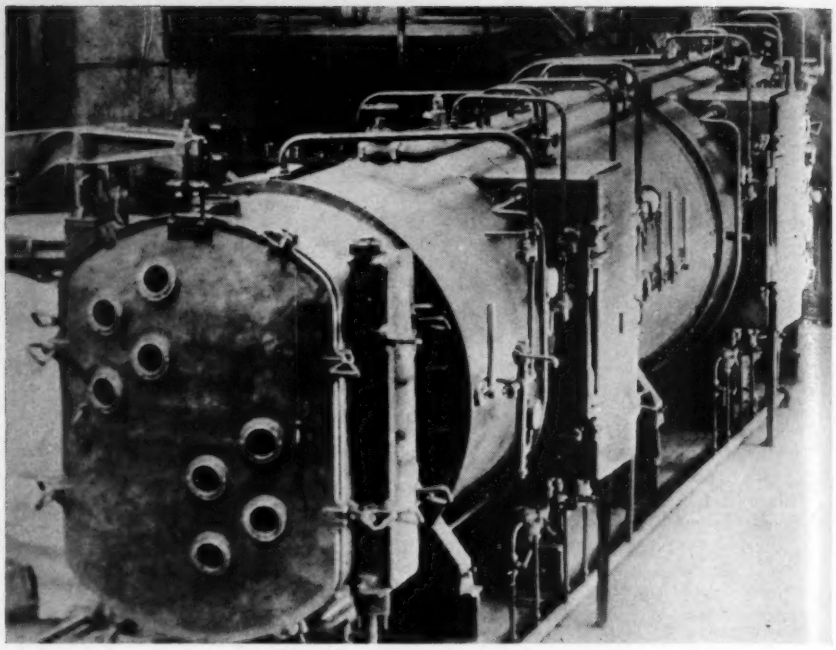
There is little new in the way of air heating, this being generally by steam in a gilled tube heater or by the use of gas or oil in indirect heating equipment.

However, considerable work has been carried out on the recovery of milk powder from the exit air stream. The tendency up to a few years ago was to replace the previously used, relatively large, dust cyclones by textile filters, and extremely efficient recovery of dust was obtained by the use of fully-automatic textile filters with provision for reverse-flow blow down. An efficient textile filter, however, is a very large unit, expensive to buy and calling for quite a considerable amount of maintenance. It could never be said to be a completely sterile unit, as by the nature of the filter unit it was impossible to completely free the fabric of milk powder.

More recently, therefore, the tendency has been to use a multi-cyclone unit employing a larger number of smaller cyclones, or batteries of relatively small cyclones of, say, 6 or 7 in. diameter mounted in tubeplates. These units have been found to be extremely efficient and tend to show a superior dust recovery over the conventional cyclone, even of the smaller size.

Another type which is understood to be extremely efficient is the system in which the air is blown into specially slotted cone-shaped separators in which the dust particles are concentrated and discharged at the bottom of the cone, the air stream virtually doubling back on itself and passing out through the slots. These units are employed in series with dust cyclones between the series and with return air circuits to increase efficiency further.

In all these various cyclone and similar units facilities are given for cleaning, although it is found that in the majority of cases the type of unit employed becomes virtually self-scouring.



High-vacuum band drier.

In many driers now used there are virtually two separate discharges, one from the main drying chamber and one from the dust recovery apparatus, and the application of electrically- or hydraulically-operated vibrator conveyors is particularly attractive, as they completely eliminate all mechanical moving parts such as screw or chain conveyors and they also lend themselves to construction at a relatively low cost in stainless steel.

These collectors are usually arranged so that the powders from the various sections of the plant are collected in one trough giving a common discharge.

One of the main factors on which the size of the dried milk particles and, therefore, density, etc., depends is the speed of the atomiser. Compromise has to be reached between optimum powder density and the eventual dust recovery from the air stream and these factors vary to a certain extent according to whether full cream, skim or other milk product powders are being handled. It is, therefore, of considerable advantage to provide for variable speeds on the atomiser and provision is usually made for this either by variable speed gear or by the use of the direct electric drive mentioned.

Spray drying is again a process which lends itself to automatic control. This is usually applied to the control of the heat input and temperature of exit gases, these being connected with the feed system. The apparatus employed here is of conventional type and presents no particular problem.

A spray drier can be used for a number of milk products other than full cream and skim milk, but in certain cases a more satisfactory product, particularly of a granular nature, can be obtained by the use of a continuous vacuum band drier.

This unit consists essentially of a horizontal, cylindrical chamber in which are mounted a number of slow-moving endless bands made of closely-woven wire which travel through the chamber over steam- or hot-water-heated plates. The unit is usually operated under a vacuum of the order of about 29½ in. ore more. Feed, which is usually to each of the various bands simultaneously, is through a pressure pump, the feed being distributed over the bands by feeding combs consisting of carefully graduated tubes. The consistency of the feed liquor should be that of a heavy cream and for easy reference one might refer to standard malt extract which is ideally handled in this type of unit.

The hot plates in the machine are arranged in series so that the temperature of heating can be graduated in the length of the drier and, with certain hygroscopic products, partial cooling can be carried out before discharge. At the same time the speed of travel through the drier can be varied through a very wide range, usually of the order of 20 to 60 min.

The operation of the machine can be best described as the production of a solidified foam at the discharge point, where it is broken off by mechanical means and drops through a discharge breaker into the first of a pair of discharge hoppers which permit intermittent discharge of the product. In the upper hopper a built-in grinding unit may be employed to reduce the material to a powder. This application is particularly useful, as any generation of heat due to the operation of the grinding mechanism is immediately

(*Concluded on page* 383)

FRACTIONAL DISTILLATION—2

Bubble plate columns, perforated plates, wetted wall columns, extractive and azeotropic distillation, batch distillation, industrial operation, low temperature separation

By H. H. M. Jones, B.Sc., A.M.I.Chem.E.

Bubble plate columns

THE mechanism of bubble-plate operation and means for its better understanding leading to improved efficiency have again been investigated by many workers and from many aspects. The basic concept of mass transfer through the slots of a bubble cap have been simplified by Bakowski,[87] who considers each separate passage of vapour from the perforate edge of the bubble cap through the liquid as a wetted-wall column. An equation, for local efficiency, based on this hypothesis shows the log of the reciprocal of the Murphree efficiency to be directly proportional to the slot submergence, the 0.5 power of the absolute temperature, inversely proportional to the 0.5 power of the molecular weight, the 0.25 power of the vapour rate through the slot and the 0.25 power of the absolute pressure. Good agreement is claimed between predicted and measured efficiencies.

Kondo and Fujita[88] used the operational data on three reported binary systems, methyl alcohol/water, ethyl alcohol/water and benzene/toluene, with the same construction of tray in each case in order to calculate the point efficiency and to plot this against the number of plates. Actual details of the calculations are given. However, Shilling *et al.*[89] carried out a series of experiments to determine ethanol/water fractionation using a three-plate 18-in. diameter bubble-cap tower with ten 3-in. caps to each plate. Experiments covered a wide range of ethanol strength and reflux ratio and all runs were effected at the same vapour velocity. Plots were made to show the Murphree plate efficiencies and point efficiencies. Local efficiencies were found to be independent of reflux ratio and to range from 30 to 45% at low concentrations of ethanol and to a maximum of 85% for concentrations of 40 to 65 mol. % ethanol. Chu *et al.*[90] give two methods for evaluating plate efficiencies, each leading to the final calculation of the number of actual plates. Two expressions are given for the calculation of bubble size, depending on whether the flow is streamline or turbulent, but a correction depending on the ratio L/V may have to be applied at very high values of this factor. A second method is more approximate and involves the estimation of overall plate efficiency by means of an equation correlating L/V, effective submergence, relative volatility of the key components and the viscosity of the feed. Fluid dynamics of bubble-plate operation are reviewed by Houghland and Schreiner,[91] and experiments with rectangular-shaped caps are reported. Cross and Ryder[92] conducted experiments by bubbling air into water through bubble caps which showed that below a certain critical velocity of the rate of air passage surface-tension effects are more important than hydrodynamic factors, whilst at higher rates the extent of slot opening varies as the rate of air passages raised to some power (less than unity), the extent of the latter being dependent upon the shape of the slot.

In another paper Cross[93] shows that the slot dimensions are related to the surface tension of the liquid phase and should follow closely a theoretical curve corrected for changes in vapour density and for surface tension of the liquid phase. Experiments were conducted with acetic acid and water, and close agreement between theory and practice for the correlation between slot opening and flow rate was obtained. The behaviour of bubbles passing through liquids and how the mass transfer will vary with the operational conditions is fundamental to the proper understanding of bubble-plate mechanism, and Coppola and Hughes[94] thus confined their experiments to the effect of the size and velocity of the bubble on mass transfer, while West *et al.*[95] carried out mass transfer study to determine how the point efficiency varied with bubble size and extent of foam voids. They used a perforated plate in the humidifying of air with water and CO_2 absorption and desorption. Using Higbie's[96] equation, an equation was derived relating Murphree point efficiency to vapour and liquid diffusivities. They found agreement between calculated and observed values poor, probably owing to inaccurate values for the fraction of voids in the foam and in estimating the average bubble radius. There were also indications that, for bubble-cap plates with good agitition, plate orifice or slot size may not be important. The practical application of the limitations of bubble-cap design were dealt with by Freshwater[97] from a consideration of fixed and operating variables, while Zenz[98] suggested a new method of tower design in which the individual bubble cap is designed before the tower diameter is estimated.

Perforated plates

Increased attention has been paid recently to investigating the possibilities of perforated-plate columns. These have been established almost by tradition for many years in the alcohol industry, but have found only small scope outside, mainly because of their alleged limited range of capacity and difficulty of correct installation. Their advantages in terms of low capital cost, however, caused Wayfield *et al.*[99] to embark on an extended programme of investigation to obtain data not previously available. Experiments carried out on trays of 6-in. diameter and above showed that the perforated plate can be relied upon for a wide range of stable operation and that for certain separations it was more efficient than the bubble plate. The experiments were comprehensive in scope and the results were used to design a sieve plate for many industrial-size columns up to 11-in. diameter, the installation of which is described by Keck.[100] Arnold *et al.*[101] also carried out experiments on perforated-plate columns mainly to determine limiting air velocities for different proportions of perforation and pressure drop at varying vapour rates. Air and water were the two fluids considered and it was found that for stable operation the total measured pressure drop could be predicted approximately from the sum of the dry plate pressure drop plus the static liquid seal.

Wetted wall columns

The mechanism of a wetted-wall distillation column has been investigated, though it has not obtained an industrial application nor, indeed, on its present showing can one be expected. Thornton[102]

found that the efficiency of such a column is improved by subjecting the liquid and vapour phases to a rapidly-oscillating pressure, thereby increasing turbulence and producing a large interfacial area for mass transfer. Lindsey *et al.*[103] carried out conventional binary separations in a column of seven $\frac{7}{8}$-in. water-cooled copper tubes and found that, if these were first etched with a mixture of nitric and sulphuric acids, a uniform flow of reflux could be obtained. However, H.T.U. and H.E.T.P. values were high and comparison of these values with those for columns packed with Raschig rings or *Fibreglass* showed that the wetted wall is inferior except at low reflux ratios. Although the pressure drop is low when compared with a *Fibreglass*-packed column, on the basis of pressure drop per H.T.U. it possesses no advantage. In a variation Martin[104] carried out investigations with the column which combined certain of the advantages of a bubble plate with those of the wetted wall. It consisted virtually of plates having short pieces of tube set into them and these tubes of successive plates being offset. Vapours pass up the tubes (serrated at the bottom and not completely sealed by the liquid level on the plate) from plate to plate and in passing from one set of tubes to the other turn through 90°. Data on the distillation of tri- and tetra-chloroethylene are presented and show that at vapour velocity greater than 6 ft./sec. the H.T.U. decreases sharply. The liquid flows down the tubes from plate to plate and at the most efficient vapour velocity drops of liquid are swept up the tube, but are removed during the change of the direction of the vapour leaving the tube. It has been clear that the wetted-wall column consisting of one or many long vertical tubes has a limited industrial future, and it would seem that investigations along these lines might be an effective compromise, enabling the advantages of a wetted-wall column to be retained whilst eliminating some of the mechanical obstacles. Finally, Kamei *et al.*[105] carried out experiments on the relationship between operational variables in an adiabatic wetted-wall column.

Extractive and azeotropic distillation

In this field the important papers of Horsley *et al.*[106] have been collected and published and form a most useful reference book on all known azeotropic systems. Bonauguri[107] discusses the formation of binary azeotropic mixtures between various groups of components. Using as parameters the composition of the azeotropic mixture and the boiling point of one component, analogous groups of curves are formed for one series of compounds. It is stated that the limiting factor is the difference in boiling points of the two compounds. Among the new azeotropes which have been discovered is one by Brown and Whitt,[108] who reported one at 866°C., between phosphoric oxide and water, while at more conventional lower temperatures Marschner and Burney[109] claim the discovery of three azeotropes involving only paraffins, *viz.* cyclohexane-triptane, cyclohexane-2-2-4-trimethyl-pentane, and cyclopentane-neohexane. This phenomenon, therefore, would appear not to be as rare as was once thought. In the field of extractive distillation, Ellis[110] summarises the theoretical background with sections on vapour/liquid equilibrium relations, selection of solvent and various applications. Systems which have been studied are also listed. Hetherington,[111] in the course of a paper reviewing the principles of fractional distillation, gives details of the separation of 2.6 lutidine, β-picoline and γ-picoline through formation of azeotropes with acetic acid or water. The important industrial separation of *n*-butane and the 2-butenes was investigated by Hess *et al.*[112] Since the relative volatility is only 1.07, it is not feasible to separate these on a commercial scale, and solvents best suited for the extractive distillation were found to be aniline and furfural modified by water. Experiments with a continuous pilot plant are detailed. It is known that the plate efficiencies in extractive distillation columns are generally low, and Kammermeyer and Lee[113] show that this may be correlated with the viscosity of the liquid phase.

The graphical calculation of the distillation of acetic acid and water by the use of toluene as an entrainer is due to Otero.[114] The method may be used for batch operation and to systems in which ternary heteroazeotropes and binary or ternary azeotropes occur. Hetherington[115] proposes an approximate equation to relate the volatilities of the two components with that of the non-volatile extractive solvent.

Batch distillation

There have not been so many papers on practical work reported under this heading as has been the case previously. Rose and Johnson[116] have continued their study of the theory of unsteady-state distillation and the particular application of digital computors in this connection. In batch distillation, many problems were previously too laborious without resort to these machines, and the paper indicates a way in which they may be used in their solution. Rose *et al.*[117] investigated batch-distillation calculations reported previously and these are compared with those for continuous distillation calculated on the same basis. They deduce that, depending on the degree of hold-up, either of the two methods of fractionation may be the more advantageous. Their findings in general confirm the conclusion reached by Lloyd.[118]

Previous papers have dealt with binary mixtures, but in another paper Rose and O'Brien[119] turn their attention to ternary mixtures and the effect of hold-up/charge ratio on such fractionations. Experiments were carried out in which this proportion varied from 7.5:1 to 60:1, and it was determined that the important factor with any multi-component mixtures is the ratio of column hold-up to the quantity of two adjacent components which it is desired to separate. Treub[120] followed up previous papers[121, 122] dealing with the theory of batch distillation by presenting a chart which illustrates the number of plates required to give a residue of a certain composition when the feed and distillate compositions have themselves been fixed. The diagram refers to binary systems and its use is explained by reference to the separation of coconut-oil fatty acids. Rose *et al.*[123] were concerned with the effect of column hold-up and reflux ratio in binary batch distillation. Their main results are summarised in a single graph and for the first time show the favourable and unfavourable effect for all combinations of the variables for a particular column and mixture.

The analytical calculation of batch column for binary separation is treated by Zuiderweg,[124] who has extended the 'pole height' concept from the determination of minimum reflux ratio and number of plates so that it can be used for practical problems.

Industrial-scale operation

There have been several papers which either report on industrial fractionating processes or bring to bear on it the views of men with much practical experience of this unit operation on a large scale. In the first category Keck[125] describes a partly constructed petrochemical plant based on C_3 and C_4 hydrocarbons and, in particular, makes mention of the use of perforated trays to replace bubble trays in fractionating towers and liquid extraction. Flow-sheets for the distillation units are given. Marks[126] describes the practical uses to which the by-products obtained in modern alcohol distillation can be put.

In the industrially important separation of butyl alcohol from water there is formed a troublesome heteroazeotrope, and Aza[127] makes certain suggestions as regards feed temperature, whether or not to use partial condensation and what part of the heteroazeotrope to return in order to effect the most economic operation. The McCabe-Thiele diagram for this system is discussed and suggested modifications are indicated. Separation processes as seen from an industrial viewpoint are dealt with by Hackmuth.[128, 129, 130] In the first of these the basic analogy between all separation processes is stressed and practical guidance is given by which the ease of otherwise of a process can easily be recognised. An approximate method is outlined for estimating the separation in a primary tower without taking into account recycling streams, and a procedure is given for estimating non-ideal multi-phase equilibrium from easily obtained two-phase equilibrium. Emphasis is placed on obtaining practical solutions to separation problems and only applying rigorous methods

where approximations would obviously serve no practical purpose. In the second paper the more familiar calculations used in separating processes are reviewed, while in the third the concept of basic similarity between various separation problems is stressed as revealing short cuts and aid in solving unfamiliar ones; in this connection the absorption factor is seen as a powerful tool not perhaps yet fully utilised.

Low-temperature separation

This specialised field of industrial fractionation has always been given a more thermodynamic bias than others, since the economics of the operation require this. Several papers were read at the 8th International Congress of Refrigeration which dealt with the developments of the technique of gas separation. Pearce[131] reviews these papers which included, in addition to the normal problems of the separation of air into commercial products, the recovery of ethylene from cracker gas and the use of automatic controls in separation plant. This last aspect is dealt with in much more detail by Ruhemann,[132] who discusses a plant control system on the basis of the determination of the number of controllable streams under particular design conditions. Those of the latter which should be used to control each stream are described for plants producing pure light hydrocarbons from cracker gas and oxygen and argon from air. Monna *et al.*[133] gave a mathematical analysis of rectifying columns for air separation, the feed being considered a mixture of oxygen and nitrogen only. Relations between upper and lower sections of the double column are derived based on the 'equivalent latent heat' approach of Peters.[134] In two general papers, Davies[135] and Roberts[136] review the unique design problems involved in the commercial-scale separation of gases from air.

General

There have been some reports on fractionation columns of improved or radically new design. Cannon[137] suggests a plate where the vapour from below is throttled through the liquid by Venturi-like tubes creating a high degree of turbulence. It is claimed that the use of this principle gives a column having a much greater capacity and also smaller plate spacing. Thornton[138] discusses somewhat similar so-called Venturi trays with a chart for sizing them. Rollett[139, 140] continued his investigation of the operation of a horizontal glass column previously described.[141] This time the column operates under reflux and curves have been determined for various test mixtures. It seems that there was a sharp decrease in column efficiency above the optimum reflux rate; a mathematical formula is developed which permits the approximate prediction of efficiencies of similar columns under different operating conditions. Mason[142] suggests a modification to the Vigreaux column to enable it to operate without accumulation of reflux. The new *Turbogrid* tray developed by Shell has been described.[143, 144] The basic simplicity of the design of this tray, consisting as it does of horizontal slots, has certain definite advantages as regards hold-up, first cost, pressure drop, etc., which more than offset its reduced efficiency when compared with conventional trays.

In certain industrial operations carried out on a very small scale the effect of sampling on the efficiency of fractionation can be important, and Romanet[145] found that, when distilling a mixture of citronellal and geranial under vacuum, intermittent sampling is more efficient than the continuous sampling only at high reflux ratios. General problems in distillation are reviewed by Garner and Norman,[146] who note the recent advances in the thermodynamic theory and the lack of adequate knowledge of the mechanism of diffusion.

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Milk Processing Plant

(*Concluded from page* 380)

absorbed by a slight evaporation of the contained moisture and at the same time the powder is, of course, maintained in the de-aerated condition.

The drying temperature of the material is usually about 70 to 90°F. and it is, therefore, possible to handle extremely heat-sensitive materials by this system.

A band drier has definite applications for the production of materials such as milk chocolate mass, milk-chocolate-malt-egg and similar breakfast foods, malted milk, etc. It can hardly be described as an efficient unit for the handling of straight milk, although milk powder produced on this machine is of excellent quality. By the nature of the machine its throughput is relatively low and, therefore, can find application only for relatively valuable foodstuffs.

For certain special products the bands can be arranged to discharge one to another so that the material can make several passes through the drying cylinder before being discharged. This has an application in the handling of certain pharmaceutical products of milk base where the drying of the material is more difficult. Continuous vacuum milling and sifting can be incorporated in the one unit.

As an alternative to bands the hot plates are in some cases constructed in the form of continuous trays with drag mechanism for the movement of the material.

Thanks are due to the directors of George Scott & Son (London) Ltd. for the use of illustrations, etc.

METALLURGY

Rare earth and boron alloy steels, corrosion, magnesium, titanium, zirconium, molybdenum, vanadium, 'rare' metals

By H. A. Holden, M.Sc., A.R.C.S., D.I.C., A.I.M.

FERROUS

Boron steels

ALTHOUGH the main emphasis in alloy steel development still appears to be in the fields of corrosion and heat resistance, the sigma phase,[1, 2] the rare earths as alloying elements and boron steels continue to attract increasing attention. In particular, the manufacture of boron-treated, low-alloy, heat-treatable steels in the U.S.A. is now well beyond the experimental stage where there is considerable experience of their behaviour in service, particularly in the automobile and allied industries.[3, 4] Knowlton,[5] in fact, has published a table showing where such steels are used in American automobile components. The primary purpose of the boron additions is to increase hardenability and, as a result, it is claimed that appreciable savings in strategic metals such as Ni and Mo can be made by replacing relatively highly alloyed steels by boron-treated steels with a lower alloy content.[6, 7, 8, 9]

American manufacturing practice has been reviewed by Udy[10] and Berry[11] with particular reference to acid electric furnaces. The optimum boron content is stated to be 0.001 to 0.003% or somewhat higher in low-carbon heats and electric furnace practice and for the best results the steel should be fully deoxidised and fine-grained, additional aluminium, titanium or zirconium being necessary.[12] The boron may co ıveniently be introduced as ferro-boron and other alloys (supplemented by aluminium and other degasifying agents) or in complex boron-containing deoxidation alloys, but the work of Speight[13] in this country suggests that adding boron by reduction from a slag containing boric oxide offers considerable promise. Correct quenching and tempering is important for the maximum hardenability effects[14] and, although boron in cast steels increases the hardenability of carbon and low alloy steels in the same way as for wrought steels, it has been reported that tempering at 1,200°F. destroys the effect of the boron.[15] Very generally speaking, American claims[10] are that, within normal limits, the boron additions to a given base metal do not affect tensile properties, temper brittleness, creep resistance at elevated temperatures, endurance, forging, machining[16] and welding characteristics and corrosion resistance.

In the application of the steels, almost the only criterion of suitability has been the Jominy test; substitution of the boron steel for the more highly alloyed steels being on the basis of approximately equal hardenability for the section under consideration. Consequently, in the American information there is not much data of the type required by British designers on the mechanical properties in various ruling sections, nor can a comparison be made between boron-treated and boron-free steels of the same compositions. To provide this type of information Wilcock[17] has recently reported an important series of tests carried out at the works of Samuel Fox & Co. Ltd., Stocksbridge. Five low-alloy steels, each with one ingot treated with boron and one without, were made to the following compositions:

Type of steel	C, %	Mn, %	Ni, %	Cr, %	Mo, %
En 15	0.35	1.45			
	0.35	1.45			0.10
	0.35	1.45			0.20
En 16 ..	0.35	1.45			0.28
NE 8640 modified	0.40	0.90	0.55	0.40	0.12

The modified American NE 8640 type with reduced molybdenum was included as being typical of the low-alloy boron steels used in the U.S.A. as substitutes for higher-alloyed material. Tensile and impact tests in the hardened and tempered condition were performed in a range of sizes up to 4-in. square and the hardenability investigated by Jominy end-quench tests and hardness traverses. It was confirmed that, in all the steels examined, boron increased the hardenability as shown by Jominy end-quench tests and hardness traverses; in certain sizes boron additions induced a tensile strength unobtainable in the same steel without boron, except by tempering at temperatures lower than those usually considered suitable; on the basis of specifications En 15, En 16 and En 17, the molybdenum saved in 1½% Mn steels with Mo varied from nil to 0.2%, depending upon size. In another series of tests at the United Steel Companies[18] boron was added to low-carbon, low-alloy steels to produce high U.T.S. and yield-stress values in the as-rolled or normalised condition. With 0.15% Mo in an 0.14% C steel the effect was negligible, but at 0.44% Mo the U.T.S. was increased 48% and the yield strength more than doubled.

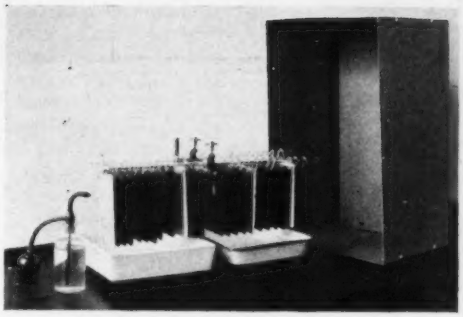
Boron steels have also received some attention on the Continent. In Germany, Krainer and Kroneis have reported their experiences with boron additions to structural alloy steels,[19] and Scherer, Bungardt and Kunze[20] have investigated the substitution of alloying elements by boron in case-hardening and heat-treating steels. They conclude that there is little likelihood that boron can replace molybdenum or nickel in German steels. General reviews of the subject have also appeared in France[21] and Spain.[22]

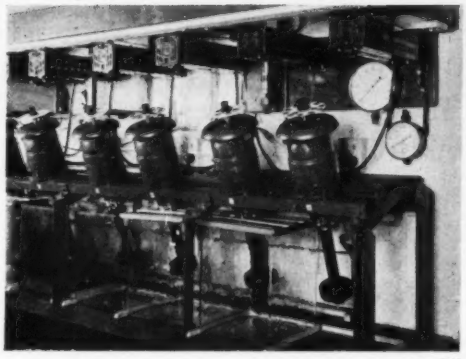
Rare earth additions

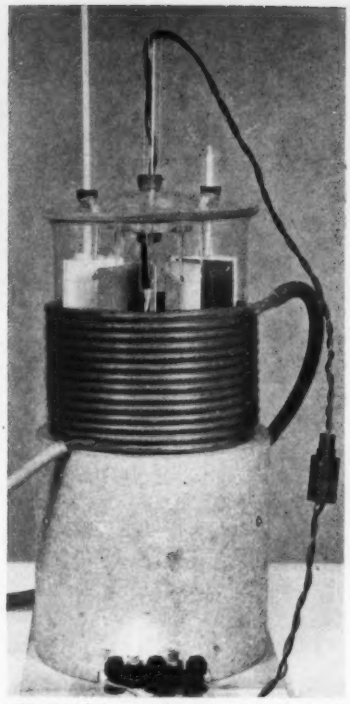
Further information has been released concerning the beneficial effects on their hot workability of cerium and lanthanum additions to certain high-alloy, heat- and corrosion-resistant materials. In 1951 it was established[23, 24, 25] that these elements improved the hot workability of steels containing 4 to 70% Ni and 10 to 60% Cr + Mo + W, the amount of any one element in the latter group not exceeding 30%. The Carpenter Steel Co., U.S.A., employs cerium, lithium and lanthanum to improve the hot-working properties of alloy steels.[26] Lillieqvist and Mickelson[27] have published the results of their investigation of the effects of additions of a proprietary rare-earth-containing alloy on the properties of cast steel. No detrimental effects were noted and definite improvements were found in ductility, impact strength, inclusion shape and distribution, hot tearing, fluidity, sulphur reduction, porosity, weldability and feeding characteristics. Also Knapp and Bolkcom[28] have reported on *Lan-cer-amp*, a rare-earth mixture containing rather more lanthanum than regular Mischmetall. Ladle additions at the rate of ¾ to 6 lb./ton to stainless, tool, alloy and electrical steel grades resulted in treated steel castings showing higher impact and ductility in quenched and tempered condition than untreated heats. Transverse impact values at −40°F. on 0.32% C chromium - nickel - molybdenum forgings were increased from 12 to 20 ft.lb. Increased fluidity was also reported and less grain coarsening in austenitic stainless steels, type 310.

Corrosion protection

Hot-dip galvanising is one of the best established methods of protecting iron and steel surfaces from corrosion. Therefore, it is particularly interesting to learn from tests by the British Non-Ferrous Metals Research Association[29] that, by annealing hot-dipped galvanised wires and sheets, the resistance to atmospheric corrosion in







[Photos: The British Iron and Steel Research Association

Apparatus for testing resistance to corrosion. Top left: the A.R.E. salt droplet test. Bottom left: five rotor test units of the Chemical Research Laboratory, Teddington. Right: the C.R.L. sulphur dioxide test, which reproduces under controlled conditions the corrosive effects of industrial atmospheres.

Central London was substantially increased. The longest life obtained was more than three times that of an unannealed coating. As an alternative to zinc for protecting steel when exposed out of doors, aluminium is rapidly gaining favour, especially when applied by metal spraying. The application of aluminium by hot-dipping, however, has recently received considerable attention and is now claimed to be a commercial proposition.[30, 31] The General Motors procedure involves preheating and fluxing before dipping in the induction-heated molten aluminium bath[32]; Russell[33] has described a process for the continuous coating of steel wire or strip involving degreasing, pickling, washing, preheating, coating and cooling; and the Al-Fin process[34, 35] entails aluminium dipping followed by casting an aluminium alloy against the prepared surface. Another growing use for aluminium coatings is as a cladding material for steel, where advantages can be taken of its heat-reflecting and -resisting properties and its ability to resist corrosion at elevated temperatures.[36]

A new approach to the problem of developing heat-resistant materials for gas turbine and similar applications is the use of special high-temperature-resistant ceramic coatings.[37, 38] Three such coatings have been developed by the National Bureau of Standards.[39] The one used on carbon steels has a softening point of 1,100°F. and the other two for stainless and other alloys can stand >2,000°F.; in fact, coated *Inconel* sheets have successfully withstood 2,200°F. Proprietary treatments include the ' Solaramic Process,' developed by the Solar Aircraft Co., U.S.A., for use in jet engines—321 stainless steel coated by this process withstood 1,700 to 1,900°F. as well as *Inconel*[40, 41, 42]; and the A-418-Ryanco-C treatment of the Ryan Development Laboratories which has given excellent results on exhaust headers in Pratt and Whitney aero engines.[43] It is believed that these ceramic coatings are produced from high-barium-content, alkali-free frit containing chromic oxide (approximately 30%).

Several useful reviews of corrosion problems of particular interest to chemical engineers have appeared during the last year or so. These include a summary of the reports on corrosion-resistant, low-alloy steels and protective coatings published by British, American, French and Belgium research associations which well illustrate the beneficial effects of low amounts of alloying elements such as nickel, copper and chromium[44]; the results of 13-year tests by the National Bureau of Standards on the corrosion of low-alloy iron and steels in various soils[45]; and good practical surveys of factors governing the successful and commercial use of rust-resisting steels in chemical engineering.[46, 47] (Incidentally, Linnert[48] contends that 17% Cr steels when properly handled show as good corrosion resistance as 18/8 materials in welded parts, and Thielsch and Pratt[49] say that excellent corrosion resistance to a wide variety of sulphuric acid conditions is shown by stainless steels highly alloyed with copper, molybdenum, nickel and chromium.) Probably the most important publication is ' The Fight Against Rust,' a 25-page pamphlet published in October 1952 by the British Iron and Steel Research Association. This describes in simple terms the work of the Corrosion Committee over the past 25 years and deals with typical histories of corrosion in air, water and soils. Simple details of the applied and fundamental research carried out are given and this booklet can be recommended to all engineers.

The B.I.S.R.A. Methods of Testing (Corrosion) Sub-Committee has also published its second report,[50] which gives details of a new laboratory test—the C.R.L. (Chemical Research Laboratory) sulphur dioxide test—for assessing resistance to corrosion. When tested over a range of protective schemes for mild steel, it gave reproducible results in a number of different laboratories and fair correlation with the results of outdoor exposure. In essentials, the test consists of exposing specimens inside a covered beaker containing a dilute sulphur dioxide solution. The condensation of moisture on the specimens is brought about by an electric heater controlled by a thermostat and cooling coil.

Cold working

The cold extrusion of steel is still very much in the news. In order to spread knowledge on this most important technique, a two-day conference was held in London last May at which, in addition to British papers, authors from America and Germany also presented papers.[51] America is well in the lead in the industrial application of this cold-forming method and further general information has been given,[52, 53] as well as details of its use in the manufacture of the 81-mm. shell[54, 55] and 4.5-in. rocket nose pieces.[56] A phosphate coating as a lubricant carrier is one of the secrets of success for this method and such coatings as, for example, are produced by *Bonderizing* are also now extensively used in this country to assist steel wire drawing. This was discussed at a conference held in May 1952, when it was confirmed that the advantages of *Bonderizing* included faster drawing speeds, greater die life, reduced stoppages and the elimination of inter-anneals, etc.[57]

Miscellaneous

In view of the interest now being shown in chromium diffusion or ' Chromising ' processes, recent Russian publications on the diffusion of vanadium,[58] molybdenum,[59] tungsten[60] and manganese[61] into steel from gaseous media are of potential importance. Considerable penetration was effected in all cases, the operating temperatures being within the range 800 to 1,300°C. Improvements in corrosion protection were in-

duced by the molybdenum and tungsten treatments, but, although manganese diffusion improved the resistance to corrosion in water, the resistance to acids was diminished.

NON-FERROUS

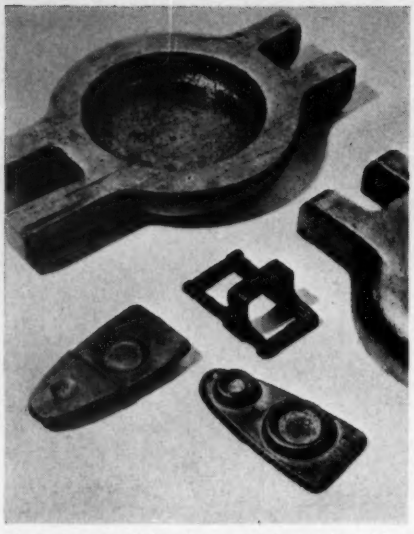
In the non-ferrous sphere, comparatively few developments of direct importance to the chemical engineer have taken place within the past year or so. *Novoston*,[62] a new copper-base marine propeller alloy with a lower specific gravity and superior mechanical properties to ordinary propeller bronze has been introduced; it has been shown[63] that copper, brass and zinc are dissolved by several commercial and experimental dish-washing detergents; and new magnetic materials include *Bismanol*[64] (an alloy of manganese bismuthide and unreacted manganese and bismuth) and the manufacture of Al-Ni-Co types by powder metallurgy.[65] With the exception of the magnesium-rare earth alloys, physical metallurgy and the academic investigation of 'rare' metals seem to have received much more attention than more practical studies.

Magnesium—rare earth alloys

An interesting new range of alloys has been opened up by the discovery that the addition of Mischmetall or rare earth elements to Mg alloys greatly improves their high-temperature properties. An average composition for Mischmetall would be: 50% Ce, 25% La, 1% Fe, the balance being other rare earths and impurities.

McDonald[66] has critically discussed the magnesium-zirconium-rare earths types of alloy from the point of view of elevated temperature service, creep, fatigue strength, corrosion resistance, foundry technique and cost. He states that the zirconium is added to refine the grain size and to prevent cracking during freezing. High mechanical properties with good creep strength are claimed for the magnesium alloys containing 0.25 to 0.7% zirconium and 3% Mischmetall, which are in some cases superseding the conventional magnesium-aluminium-zinc alloys. Creep strengths of 8,000 lb./sq.in. at 205°C. have been reported, as compared with 1,500 lb./sq.in. for the magnesium-aluminium zinc types. Even superior high-temperature properties are claimed for alloys containing 3% thorium and 2% didymium (Leontis[67] has investigated the magnesium-thorium alloys and the effect of adding 3% cerium to these). Other similar magnesium-rare earth alloys include Electron RZ5 (4.5% Zn, 0.6% Zr, 1.25% rare earths)[68] and ZT1 alloy (2.5% Zn, 0.7% Zr and 3% Th).[69]

Tests by the U.S. National Advisory Committee on Aeronautics[70] on the development of magnesium - Mischmetall wrought alloys for elevated temperature use showed that magnesium-base alloys containing 2% Mischmetall, 1.2 to 1.8% manganese and 0.2% nickel had excellent high-temperature properties. Good results



Cast shapes of titanium metal, produced by National Research Corp. of America. As reported in our November issue, complex castings of both pure and alloyed titanium have been produced in pilot quantities.

have also been confirmed for magnesium alloys containing 1% pure cerium.[71]

Titanium

As a result of the exploitation of the Canadian ilmenite deposits and improved extraction methods, comparatively large quantities of titanium are becoming available. Developments are such that in ten years time it will probably be classed as one of the common metals. It is interesting to note how the emphasis in metallurgical investigations on titanium has changed from extraction and fundamental studies of the pure metal to physico-metallurgical aspects of its alloys and their behaviour in the press shop or factory. For example, complete- or partial-phase diagrams have been published of binary titanium systems with the following elements: aluminium, boron, carbon, copper, manganese, molybdenum, nickel, niobium, tantulum, tungsten and vanadium.[72] This represents a large volume of work. Purely metallurgical tests on the metal have been confined to investigating creep,[73] strain-ageing[74] and conditions for its passivity in hydrochloric acid solutions.[75]

Much more information is now available on the applications and workability of titanium and its alloys. Aircraft production is still the major consumer, although inability to withstand high temperatures is their chief drawback.[76, 77] Wheelon[78] instances an aeroplane in which some 849 titanium parts effected a weight saving of 395 lb. over stainless and other alloy steels. Gulliksen[79, 80] has described shallow- and deep-drawing tests and reports a 38% reduction in deep drawing 0.078-in. commercial titanium sheet. Surface treatment by *Bonderizing* or anodising was, however, required before application of the high-pressure lubricant. Details have also been published of forging titanium and its alloys[81]; turning, milling and cutting[82]; grinding wheels and techniques[83]; tapping[84]; drilling and reaming[85]; resistance and Heliarc fusion welding[86] and flash-butt welding.[87] In the latter connection it is claimed that flash-butt welds can be easily made, cracking being avoided if the welded part is immediately annealed after welding.

Zirconium

Zirconium continues to attract notice in the U.S.A., although the published information is academic rather than 'practical.' Work on the double-fluoride process for the electrolytic protection of the metal has been reported by the U.S. Atomic Energy Commission,[88] together with the design of a bath for continuous operation. The purity of the metal produced varied from 99.2 to 99.9% Zr with oxygen, carbon and nitrogen as the chief impurities. Processes for the production of the ductile metal have been investigated by the U.S. Bureau of Mines.[89] The phase diagrams of binary alloys with tin, molybdenum, copper, chromium, aluminium and tantalum have also been closely studied,[90] as well as the properties of the 99.9% pure metal.[91]

Molybdenum

According to Harwood,[92] who has reviewed its methods of fabrication, welding, physical, chemical and mechanical properties, molybdenum is the most promising refractory metal. Its high melting point (2,623°C.)—which means that special methods have to be used to hot-form the metal[93]—is one of its most useful properties, but in addition it has a high Young's modulus, high thermal conductivity and a low coefficient of thermal expansion. Parke[94] has described the manufacturing techniques employed by the Climax Co. for producing 1,000-lb. ingots, and more academic data includes the effect of cold working,[95] vapour pressure between 2,151 and 2,462°K.,[96] thermal conductivity over the range 540 to 1,150°C.[97] and its ductility.[98]

Vanadium

Vanadium is a promising engineering material; it is claimed that the modulus: d ratio and its machinability is equivalent to that of steel; its resistance to corrosive attack by sea water is good; and the pure metal has a U.T.S. of 100,000 p.s.i. annealed and 140,000 p.s.i. when cold worked — the corresponding elongation values being 23% and 3%, respectively.[99] On heating in air at <600°C. a protective scale is formed, but at temperatures >700°C. a molten scale is produced. Tests to improve the oxidation resistance properties show that alloying with nickel, tantalum and titanium offer most promise.[100]

Other 'rare' metals

Everhart has compared the properties of **hafnium** with those of titanium and

zirconium and foresees a considerable future for the metal.[101]

Possible applications for pure **rhenium** include lamp filaments, and its hard oxidation-resistant alloys are already finding increasing uses as electrical contact materials, as tips for fountain pen nibs and, in the case of thin rhenium-nickel deposits, as reflecting surfaces.[102]

The importance of **lithium** is growing fast, particularly in magnesium alloys and for degassing copper alloys such as Monel, nickel-bronze, etc.[103]

Reviews of **gallium** have been prepared by Beja[104] and Wagner and Gitzen.[105] The metal has a low melting point (29.79°C.) and high boiling point (2,000°C.) and, in consequence, either it or one of its alloys has been proposed as a possible substitute for mercury in thermometers. Another possible use is for heat recovery in atomic piles. The principle objections to its application are its high price and the ease with which it alloys with other metals.

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The Chemical Plant of the Future —a German Viewpoint

THE planning and construction of chemical plants is today governed by new principles, since in recent times far-reaching changes have taken place in the character of the products, the volume of production and in the manufacturing processes. To review these principles and so arrive at some conception of the chemical plant of the future is the object of a series of articles in a recent issue of the German technical journal *Chemische Industrie*.

Continuous processing. German chemical engineers see the planning and construction of chemical plants governed by the need for the maximum of continuous processing, this being made possible by the extension and improvement of measuring and controlling techniques. A vital factor in reducing operating costs, it is pointed out, is the correct flow of materials and power to industry as a whole, and in the individual factories from the raw material to the finished product.

Automatic control. The future of automatic control is discussed in three articles. One author, fearing the automatisation not only of manufacture but also of administration, thinks that the automatic factory is by no means wholly desirable.

A very different viewpoint is put by another author, who states that the possibilities of automatic control for improving the economics of chemical processes have by no means been exhausted. He points out that it is possible to analyse the efficiency and profitability of single units employing automatic control, and to deduce data for whole factories by combining such analyses. It is important to overcome prejudices against automatic control which are still occasionally encountered, and to form a small, but highly qualified, body of operators and technicians capable of appreciating the true significance and function of automatic control.

In the third article, concern is expressed over the psychological implications of automatic control. Production processes will become increasingly anonymous and this will create psychological dangers for the operators which must be considered in future planning.

Standardisation. This is linked with automatic control. In an article in which the possibilities and limitations of standardisation are discussed, it is pointed out that in the chemical industry the wide variety of mechanical, thermal and chemical stresses, and the variety of operating conditions, make it difficult to standardise. Another point to be considered is that the further development of individual processes may be obstructed through the limitation of designs. Bearing these points in mind, the author advocates the drawing up of standard specifications for the individual structural elements of chemical plant, and also for the fabrication and testing of the plant. A kind of catalogue would thus be compiled, containing standard designs for types of plant which are frequently required and which could then be easily assembled and manufactured.

CHEMICAL INDUSTRIES OF SOUTH-WEST FRANCE

By D. C. Freshwater, B.Sc.

(Chemical Engineering Department, University of Birmingham)

A new and important centre of chemical industry has been developed in south-west France during the past 20 years. The industry was first attracted to this region by cheap hydroelectric power from the Pyrenees. Nearly all the factories operate electro-chemical processes. More recently, natural gas has been discovered in the Pyrenean foothills and the exploitation of these reserves has been undertaken by the local chemical works. Mr. Freshwater recently visited these interesting plants and here he gives his first-hand impressions, not only of natural gas processing, but also of the electro-chemical operations which include fertiliser, calcium carbide and cyanamide, and aluminium production. He also touches on the coal-based chemical industry of the area.

FRANCE has played an important part in the development of chemical technology from the earliest days of the chemical industry. One may assume the starting point of a national chemical industry in France to be the Napoleonic wars with their resulting blockade of Europe much as the 1914-18 war stimulated the growth of the industry in the U.K. However, most of this development was concentrated around Paris and in northern France. The chemical industry of south-west France is of much more recent origin and has grown up during the last 20 to 25 years in an otherwise predominantly agricultural area. A map of this region showing the various industries is given in Fig. 1. The reason for this industrial growth is principally the development of hydroelectric power from the Pyrenees, *i.e.* cheap electricity. A second and more recent influence has been the discovery and exploitation of deposits of natural gas in the Pyrenean foothills. Almost all the chemical works in this area operate electro-chemical processes, often combined with gas synthesis operations. Because of the importance of these two features they will be discussed briefly and then specific industries will be considered.

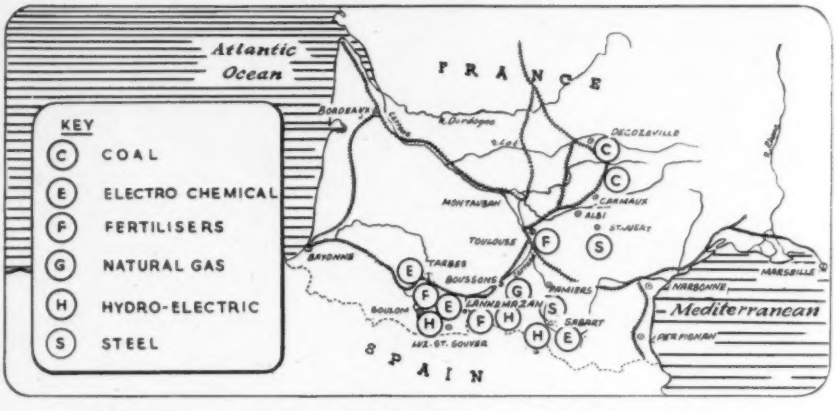


Fig. 1. The distribution of chemical industries in south-west France.

Hydroelectric power

The Pyrenees, stretching from the Mediterranean to the Atlantic and rising to a height of 10,000 ft., form a vast natural reservoir of hydroelectric power. It would appear that most of the water from the mountains runs off the French side and certainly more advantage is taken of this natural resource in France than in Spain. Generation is carried out at a number of small stations rather than a few large ones, due partly to the large area of the watershed and partly to the nature of the terrain. Small flows and high heads are generally used. The total hydroelectric power produced in this region is of the order of 5,000 million kwh. annually, which is over 25% of the total hydroelectric power produced in France. No statistics are available for the power consumption of the chemical industry in this area, but the total French chemical industry uses approximately 5 million kwh. annually.

Natural gas

Deposits of natural gas in the Pyrenees were first discovered about 1930, but were used only to supplement town-gas supplies for a number of years. Its development as a raw material for chemical synthesis dates only from 1945. However, rapid progress is being made in developing this resource and, while it is used at present only as a source of hydrogen (apart from its continued use as a fuel gas), plans are in hand for extending its application as a raw material for chemical manufacture. The raw gas has a high methane content, as is shown by the typical analysis given in Table 1.

Table 1

Constituent	*% by vol.*
Methane	89
Ethane	4·5
Propane	1.6
Butane	0.9
Higher hydrocarbons	1.1
Nitrogen	2.9

The next point to notice about the gas is the absence of sulphur compounds, a fact which greatly enhances its value because of the resulting ease of purification.

In 1949 a modern treating plant was installed by Regie Autonome des Pétroles at Boussens, near the site of the principal producing field. The purpose of this plant is to recover motor fuel from the gas and to strip out and separate the propane and butane which it contains. Gas arrives at the plant at a pressure of 1,500 p.s.i.g. The pressure is first reduced to about 350 p.s.i.g., which effects some condensation of the higher hydrocarbons in the gas. This condensation is assisted by water cooling, and a separator removes the liquid so formed. The gas then passes to two absorption towers in parallel and, after this treatment, all the higher hydrocarbons have been removed, together with 70% of the propane and 90% of the butane. The gas is treated finally in towers containing bauxite to remove the small amounts of water which it contains. It then enters a distribution mains for feeding the various towns and works in the region.

The rich absorbing oil is stripped to recover the light hydrocarbons. These are

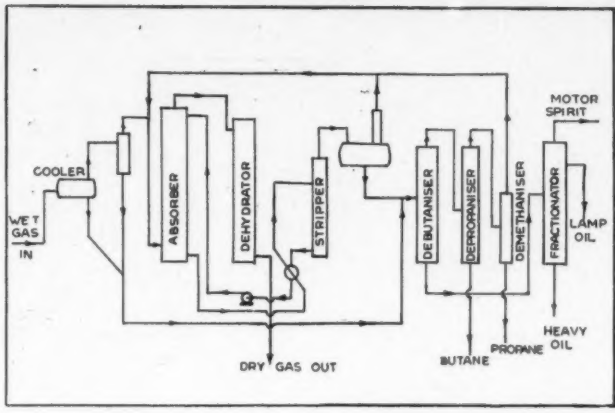


Fig. 2. Natural-gas-treating plant.

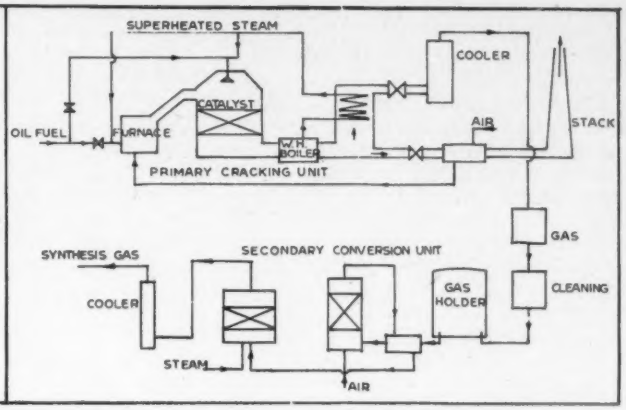


Fig. 3. O.N.I.A. plant for production of synthesis gas from fuel oil.

then stabilised and distilled in the normal manner to give propane, butane, motor spirit, gas oil and residue. A simple line diagram of the process, which is well instrumented and automatically controlled, is shown in Fig. 2.

The butane and propane are recovered as liquids at 50 and 150 p.s.i.g., respectively. The former is stored in Hortonspheres and the latter in specially-shaped vessels designed by Prof. Caquat.

The plant was designed to treat a maximum of 50 million cu.ft./day of gas and averages at present about half this throughput. Under these conditions it produces per day 13 metric tons of propane, 38 m.t. butane and 53 m.t. petrol and consumes for services 6,500 cu. ft. of gas and 9,500 kwh. per day. The capital cost of this plant is given as a milliard francs.

Synthetic ammonia production

The combination of hydroelectric power and cheap supplies of methane leads naturally to a synthetic ammonia industry, and numerous plants where ammonia and associated chemicals are produced are found in this area.

The methane is cracked to give hydrogen, whilst the nitrogen required for the synthesis is usually provided by air liquefaction and fractionation plants. The largest concern of this kind is l'Office Nationale Industriel de l'Azote (O.N.I.A.), near Toulouse, a State-owned company which began operation in 1927. It is the fourth largest producer of synthetic ammonia and nitrogen fertilisers in Europe and in 1952 production of the latter was 311,500 tons (about one-third of the total French production). Of this production, about 40% was ammonium sulphate and 25% ammonium nitrate. A number of other chemicals are made, including liquid and solid CO_2, sulphuric acid and sulphur.

Synthesis gas preparation

The synthesis gas for ammonia production is derived from three main sources as follows:

(*a*) **From water gas.** This is essentially the reaction $H_2O + C \rightarrow CO + H_2$, and is carried out by passing steam over a bed of red-hot coke. Since the reaction is endothermic, it is necessary to interrupt this process and change over to blowing air through the coke bed, the heat of combustion thus raising the temperature of the bed. This also serves to introduce into the crude gas mixture the nitrogen which will eventually be required. Automatically-operated mechanical gas producers are used and an important modification is the enrichment of the blowing air by oxygen (to about 50% by volume). This is done principally to give the correct proportion of nitrogen in the final synthesis gas after it has been treated to remove the CO and CO_2 which it contains.

(*b*) **From methane.** Natural gas containing about 94% methane is mixed with steam and cracked in a tubular furnace to give hydrogen and carbon monoxide according to the reaction $CH_4 + H_2O \rightarrow CO + 3H_2$.

The conversion takes place over a nickel catalyst at 750°C. and the resulting gas contains about 6% methane. Air is then introduced in a separate reaction chamber and this serves the purpose of removing the residual methane by combustion and also adding the nitrogen required for synthesis. The gas is then mixed with more steam and passed over a heated iron catalyst bed to convert the CO into CO_2. The final mixture containing about 30% CO_2 and 3% CO is then added to the gas from the first process prior to treatment to remove the CO_2 and CO. One of the advantages of this source of gas is that the natural gas contains no sulphur.

(*c*) **From fuel oil.** One of the most interesting recent developments in this

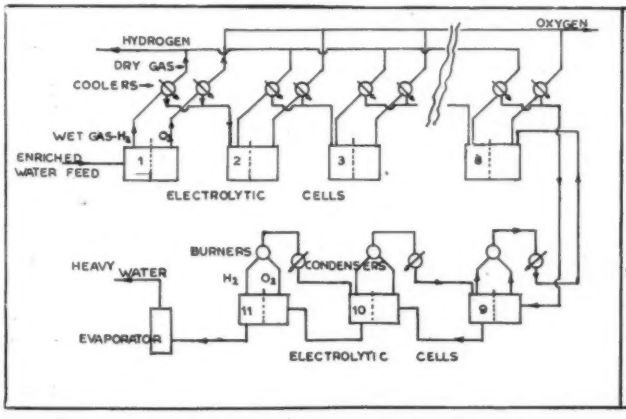


Fig. 4. Production of heavy water by electrolysis.

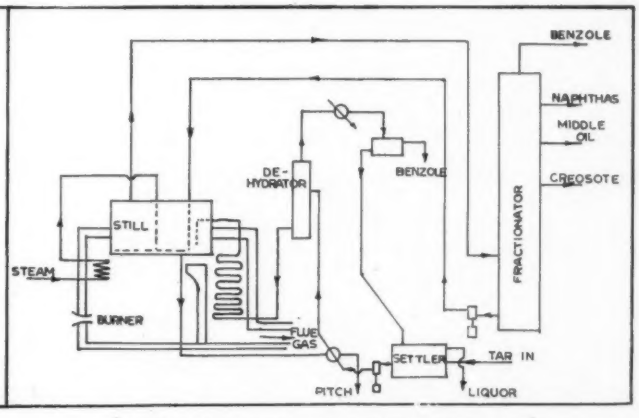


Fig. 5. Ab-der-Halden tar distillation unit.

field is the production of synthesis gas by the cracking of fuel oil at a very high temperature. A simple line diagram of the plant is shown in Fig. 3.

The primary process is cyclic, beginning with the combustion of fuel oil to preheat the catalyst bed. When this is at a temperature of 850 to 900°C. the oil is introduced directly into the converter chamber in the form of a spray. A considerable amount of carbon is deposited on the catalyst during cracking and, after about 3½ min., the oil flow is stopped and a stream of air passed through the bed in the reverse direction in order to burn off the carbon. When this has been done the cycle is complete and the sequence of events recommences. The crude gas from the primary conversion then passes through a cooler into an intermediate gas holder and thence continuously to a conventional gas-purification system. After purification it enters a converter into which air is admitted, thus oxidising the methane to CO, CO_2 and H_2O, and thence to a final converter where steam is introduced to carry out a Schift reaction.

Typical gas analyses for three stages of the process are given in Table 2.

Table 2

Constituent	*After primary cracking*	*After second converter*	*After final converter*
CO_2	7.2	9.6	21.6
CO	24	18.8	3
H_2	51.6	49.2	56
CH_4	4.5	—	—
N_2	12.7	22.4	19.4

Ammonia reaction

The various sources of synthesis gas are combined after treatment and what is virtually a mixture of H_2 and N_2 in stoichiometric proportions passes to the reaction part of the process. There are two systems practised, which differ principally in the pressure of operation. The Haber process operates here at 300 atm. and the Casal process at 800 atm. In both systems the compressed mixture is passed through tubular reactors containing catalyst at 450°C. After cooling, the ammonia condenses and separates out, whilst the unconverted gas is recycled to the fresh gas inlet. Production of ammonia is 150 tons/day. The ammonia is stored as a liquid and most of it is used for nitric acid production.

Nitric acid production

Ammonia gas is burnt with preheated air over a platinum catalyst at 800°C. to form nitric oxide, which is then absorbed after cooling in weak nitric acid. The absorption is carried out in three granite towers 95-ft. high and 12 ft. in diameter and the gas passes countercurrent to the acid. Any unabsorbed gas is treated in a further tower by a solution of sodium carbonate, to form a mixture of sodium nitrate and sodium nitrite.

Production of nitric acid amounts to 4,000 tons/day.

Ammonia from the electrolysis of water

At the works of Le Société des Phosphates Tunisiens ammonia is made using hydrogen derived from electrolysis of water (the nitrogen coming from a liquid air plant). This is perhaps the most striking illustration of the abundance of cheap electricity in this region. The electrolysis is carried out in two batteries of cells with a potential of 500 v. d.c. across each battery. The first set are of conventional design and operate at atmospheric pressure. Caustic soda equivalent to 180 g./l. is dissolved in the water to give it the desired conductivity. The cells are of mild steel

Distillation section of the natural-gas-treating plant at Boussens. The fractionator is in the foreground and from the left to right are the demethaniser, depropaniser, debutaniser and stripper (Regie Autonome des Petroles)

with nickel electrodes. They operate at a current density of 12 amp./sq.cm. and there is a drop of 12 v. across each cell. The second battery consists of a number of cells of circular cross-section held together after the manner of a filter press. These operate at a pressure of about 1.5 p.s.i.g. and there is a drop of 20 v. across each cell. A further difference is in the electrolyte used, it being potash in the latter battery.

An interesting by-product of this process is heavy water, which is worked up in this plant to a strength corresponding to about 20% deuterium. Production amounts to some 20 litres/day of pure deuterium. A simple line diagram of the concentration system is shown in Fig. 4.

Ammonia, nitric acid and nitrate fertilisers are all produced by this company along conventional lines. As their name implies, the company also manufacture phosphoric acid and phosphate fertilisers.

Calcium phosphate from Tunisia is crushed, mixed with coke and sand in the ratio of 6: 2: 1 and charged to an electric furnace. The phosphorus produced is immediately oxidised to anhydride, which is then absorbed in water to give phosphoric acid. Part of this is concentrated and purified (by settling and filtration) for sale as high-grade acid, while the remainder is used for the production of superphosphate fertilisers.

The present production of phosphates is about 500 tons p.a. A new totally-enclosed automatically-operated furnace which is being built will enable solid phosphorus to be made.

Calcium carbide and cyanamide

These are the two main products of the Lannemazan works of le Société des Produits Azotes. Production of carbide amounts to about 100 tons/day and this requires in raw materials 1,300 lb. of coke and 2,000 lb. of limestone per ton of carbide. The electricity consumption is given as 5,000 kw. per ton of carbide, the furnace operating at a power factor of 0.88. Each cell of the furnace is tapped at 2-hr. intervals, the tapping hole being reopened each time by means of an electric arc struck between the furnace at this point and an iron electrode connected to an independent source of current. The molten carbide is run into small moulds, about 3 ft. × 1 ft. × 9 in., in which it quickly solidifies; it is then crushed into coarse lumps (¼ to ½ in.) before being bagged in paper containers. The purity of the product in terms of the volume of acetylene liberated per unit weight of carbide is stated to be 90%. About two-thirds of the total production is used in the same works for the manufacture of cyanamide.

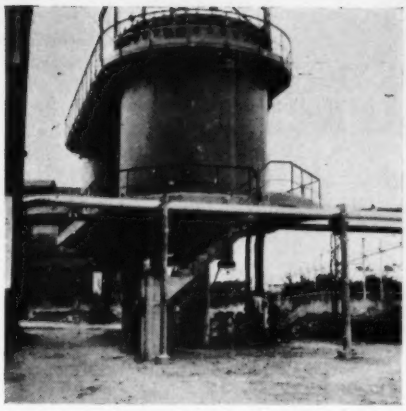
This process is carried out batchwise in large autoclaves in which the carbide is placed on perforated trays and in an atmosphere of nitrogen under a slight positive pressure. The vessels are slowly heated up to 800°C. by electrical resistance elements and held at this temperature for two days. They are then cooled by circulating nitrogen through them, this process lasting up to five days. The material in the autoclaves absorbs up to 24% of its own weight of nitrogen. For an initial carbide of 90% purity this corresponds to a conversion efficiency of about 80% assuming the simple reaction equation:

$$CaC_2 + \tfrac{1}{2}N_2 \rightarrow CaCN + C$$

The nitrogen used in this process comes from a liquid air plant. Owing to the relatively high incidence of acetylene in the atmosphere of the works, particular care has to be taken to treat the entering air to prevent explosion, since any acetylene entering the fractionation plant tends to collect in the base of the main column with the liquid oxygen. The acetylene is removed by adsorption on silica gel.

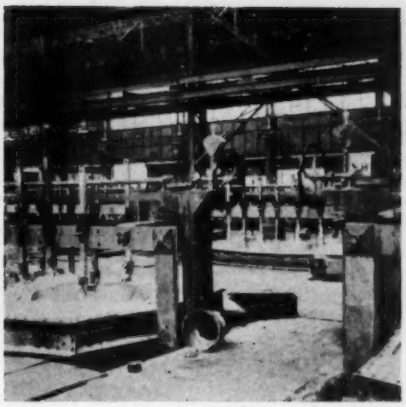
Aluminium production

The production of aluminium by the electrolysis of a solution of alumina in fused cryolite is carried out at the works of Pechiney et Cie at Sabart. It is interesting to note that this process, which is used for virtually the whole of the world pro-



Secondary convertors on fuel oil cracking plant (O.N.I.A.)

Nitric acid absorption towers (Le Société des Phosphates Tunisiens)



Battery of cells producing aluminium (Pechiney et Cie, Sabart)

duction of aluminium, was discovered originally by Heroult in France.

Production at this works amounts to 12,000 tons p.a. at a purity of 99.7%. The works is unique in having its own hydro-electric plant, most private plants having been nationalised in 1945. Current is generated at 500 v. and 30,000 amp. The electrical energy required is about 20,000 kwh./ton of aluminium. The molten metal is run off to an automatic ingot-casting machine which is capable of turning out 10-kg. ingots at the rate of 500/hr.

At the same works this company also manufactures sodium chlorate by the electrolysis of a solution of sodium chloride and sodium bichromate in water to which about 1% of HCl is added. The sodium chlorate is recrystallised and washed in an Escher Wyss continuous-pusher-type centrifuge.

Coal and by-product plants

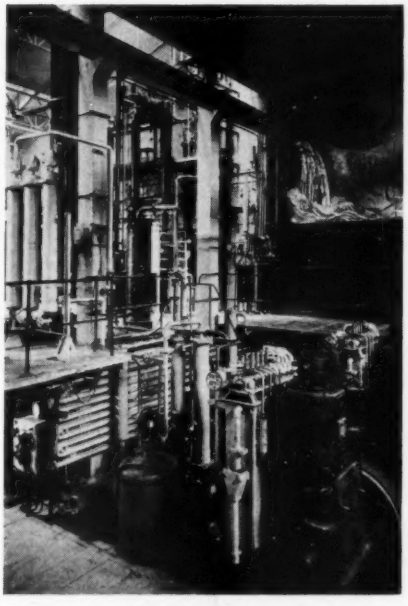
While coal is one of the most important raw materials of industry, it plays little part in the processes dealt with so far, and hence in this survey of the industries of the region it has been left to the last. There is only the one coalfield in this area, which is exploited by a semi-State-owned company, Les Houillères du Bassin d'Aquitaine, at Carmaux. Although not a large concern, it has a number of points of interest, both in the winning of the coal and its subsequent treatment.

Mining. There are two sites where the coal is mined, about 50 miles apart. At Decazeville, opencast mining is practised. Production here is about 6,500 tons/day, with an estimated life at this rate of 25 years. At Carmaux the coal is mined at 800 ft. below the surface. There are two mines, each fully mechanised, and, at one, skip winding is practised, while at the second the coal is brought to the surface by conveyor belts. In the latter instance there are two galleries each 2,200 ft. in length and inclined at 17° to the horizontal through which the conveyor belts pass. There are six belts in each, with an intermediate station at about 300 ft. below ground level. These, together with all the auxiliary conveyors which feed the main belts underground, are remotely controlled from the surface, where the operation of each belt is shown on a graphic panel. The maximum capacity of the belts is 330 tons/hr. and the total production at both these mines is 11,000 tons/day.

Treatment of coal. The central coke ovens and by-product plant for the group is at Carmaux, and the present throughput is 300,000 tons of coal p.a. The coal is screened and all the fines (below ½ in.) are briquetted. The briquetting process at Carmaux was described in an article in the November CHEMICAL & PROCESS ENGINEERING. The briquettes are sold as smokeless fuel, principally for domestic use.

The larger coal is crushed and fed to a battery of conventional coke ovens to produce metallurgical coke, gas and by-products. The gas passes through a conventional treating system, benzole and naphthalene being recovered. The tar collected amounts to some 7 gal./ton of coal. It is distilled in an Ab-der-Halden tar still, which is a type little known in this country and is a combination of a pot still and conventional tube still (see Fig. 5). A feature is the relatively large amount of stripping steam used, which amounts to 0.1 lb./lb. of tar. The unit produces a pitch melting at 72°C. (R. and B.).

Although a number of sidestreams are taken off corresponding to light oils, naphthalene oil and so on, only the top products containing benzene and toluene are worked up in further plants. The other fractions are sold in their crude state.



Chemical engineering laboratory in the University of Toulouse

Toulouse University

The region in which these industries are situated centres on Toulouse. The University of Toulouse has the distinction of being the only French university where chemical engineering, as is understood in Britain, may be studied. The head of the chemical engineering department is Prof. Cathala, who has made many outstanding contributions to the technology of nitric acid manufacture. In addition to the undergraduate course, a considerable amount of research is done in the department, particularly on vapour-liquid equilibria.

Conclusion

This survey has not catalogued every aspect of chemical industry in this region, but rather concentrated on a few of the more interesting works to be found there. These, however, all have features which make them representative of the industries of this region. The description that has been given may serve to show the considerable industrial achievements, and perhaps even greater potential, of this less well-known part of France.

Thanks are due to the several French companies mentioned in the text for permission to quote data and to publish photographs relating to their particular plants, and also to Prof. Cathala for the information on Toulouse University.

Legal Obligations of the Chemical Engineer

Liabilities Towards Contractors

By C. B. Roos, B.Sc., F.R.I.C.

(Formerly H.M. Deputy Superintending Inspector of Factories)

In CHEMICAL & PROCESS ENGINEERING, October and November 1952, Mr. Roos dealt with the legal obligations of the chemical engineer in respect of the safety and health of his fellow employees. Another important aspect of the same subject is liability towards workers employed by outside contractors who are doing work on the factory premises. These liabilities, both statutory and common law, are outlined in this article, the term 'factory premises' meaning the whole area enclosed by the boundary walls. In explaining the responsibilities of the factory occupier towards contractors, the author also points out some useful safeguards, such as indemnity for the hire of plant.

THERE is no definition of the term 'factory occupier' in the Factories Acts, but it will normally be the person who is in legal possession of the premises, as tenant or owner; or as it has been put by one learned judge of the High Court:

'Occupier plainly means the person who runs the factory . . . who regulates and controls the work which is done there and who is responsible for the fulfilment of the Factories Acts within it.'

The most common examples of workers not employed by the factory occupier but working on factory premises are those engaged in building operations and engineering work, *e.g.* installation of plant, or electric wiring, and there may in some cases be a principal contractor and several sub-contractors. It is important therefore to take into account the rights of an injured workman against 'third parties,' by which is meant all persons other than the workman's own immediate employer.

STATUTORY LIABILITIES OF THE OCCUPIER

It cannot be too strongly emphasised that the 'absolute' obligations of the Factories Acts apply in nearly every case not only to the occupier's own employees but to any other persons employed or working on the premises.

This is clearly indicated by the wording of S. 133 which states that 'if any person is killed or dies or suffers any bodily injury in consequence of the occupier or owner of a factory having contravened any provision of this Act or of any Regulation or Order made thereunder the occupier or owner of the factory shall without prejudice to any other penalty be liable to a fine not exceeding one hundred pounds.' In the event of an accident occurring to a contractor's workman which was due to a breach of the Factories Act, the factory occupier would have to bear the full responsibility, both as regards any proceedings taken by the Factory Department for contravening the law, and any civil proceedings for damages by the contractor's workman, unless he could prove in Court that the actual offender was some other person, *e.g.* the worker's own employer, or even the worker himself. To do this he must show, to the satisfaction of the Court (*a*) that he has used all due diligence to enforce the observance of the Act and (*b*) that the said person has committed the offence without his consent, connivance or wilful default. If he can prove this he is adjudged not guilty of the offence and the other person is convicted and would presumably also be liable for any damages awarded to the injured workman.

Common breaches of the Act

It may be useful, therefore, to indicate the particular breaches of the Factories Act which are frequently the cause of accidents to contractor's workmen. One of the most common is where a workman engaged in whitewashing, painting or electric wiring near the ceiling of a workroom is caught by overhead shafting, often with fatal results. Under Section 13 of the Act such shafting is safe by position so long as, but only so long as, effective steps are taken to ensure that no person approaches it while in motion. If approach is necessary the shafting must either be stopped, or securely fenced by complete enclosure, which is the only effective method.

It is suggested that, in order to be exempted from liability, the occupier would have to prove in evidence that the contractor had allowed his worker to approach the shafting without notification and without asking for it to be stopped, that he (the occupier) had no knowledge that the work had to be done near the shafting, that he had not authorised it and that he had specially warned the contractor of the danger of allowing work to be done with the shafting in motion.

Section 14 of the Act requires all dangerous parts of machines to be securely fenced so that, if a contractor's workman were to stumble near, and be caught by, unfenced gears or other dangerous parts of machines and be injured, a case would be against the factory occupier and not against the worker's own employer. It is interesting to note that the wording of both Sections 13 and 14 contains the expression 'every person employed or working on the premises,' clearly indicating that contractor's workmen are included. There is, however, one rather curious exception. The proviso to Section 14 (1) allows an automatic guard to be used where a fixed guard is impracticable, provided that it automatically prevents *the operator* from coming into contact with the dangerous part. If, therefore, a worker other than the operator, whether employed by the occupier or not, is injured by a dangerous part of a machine which has been provided with an efficient automatic guard, there is no breach of Section 14.

Other examples of breach of statute which frequently involve injury to a contractor's workman are where vessels containing dangerous liquids are not fenced or covered as required by Section 18; where trapping occurs between a fixed structure and the traversing part of a self-acting machine, *e.g.* a spinning mule or a metal planing machine (Section 19); or where a contractor's worker falls down an unfenced lift well (Section 22 (3)); or is trapped between the moving cage and any fixed structure or between the counterbalance weight and any other moving part of the lift (Section 22 (5)). This applies especially to persons sent by the lift manufacturer to 'service' the lift, and the only absolute safeguard for the occupier against liability for accidents to such workers is to ensure that the lift is immobilised, *e.g.* by locking the motor starting switch and removing the key, for the whole period during which workers are inside the lift well.

Contractor's workmen have frequently received injuries—often fatal injuries—while working on or near the track of an overhead crane. Section 24 (7) requires effective steps to be taken to prevent the crane approaching to within 20 ft. of a spot where men are working, and various methods are adopted to ensure compliance with this requirement. If the crane can be immobilised by locking the switch and giving the worker the key, the problem is

simple, but if it is necessary for the crane to be operated, *e.g.* in shops where continuous processes are carried on, one effective method is to fix stops on the track at least 20 ft. away from the danger point.

Safe means of access

There have been a considerable number of civil actions based upon an alleged breach of Section 26 (1) of the Act, which requires the occupier to provide and maintain safe means of access to every place at which any person has at any time to work. It has been held that 'means of access' applies to every means of access to every place of work without exception, including roofs and tall chimneys. In the case of Lavender *v.* Diamints Ltd.,[1] a window-cleaner had to climb over an asbestos-sheet roof to gain access to certain windows. He fell through the roof and was injured and the presiding judge held that the sub-section applied to both the inside and the outside of the factory 'within the curtilage or precincts where any person has to work.' A ladder, or a plank laid across a ditch is a 'means of access' and, further, a worker is using a means of access simply by moving across the factory floor to a place where he has to work. Means of access has been held to be unsafe because of a structural defect (see Lavender *v.* Diamints Ltd. above); where a plank across a ditch broke (Hosking *v.* De Havilland Aircraft Co.)[2]; where corrugated iron sheets forming a roof were supported by unsound timber which gave way beneath a builder's labourer (Whitby *v.* Burt, Boulton & Hayward Ltd.)[3]; and where the factory floor had been rendered unsafe by obstructions which were dangerous to workmen, especially when carrying loads or moving backwards. Trivial faults or defects in floors, however, *e.g.* patches of oil or slight unevenness, are usually disregarded by the courts as a cause of action, although the Court of Appeal decided in one case that a ladder constituted an unsafe means of access when it rested on a smooth floor where it was liable to slip and no precautions were taken to keep it from slipping.

It will be noticed that the contractor's workmen are definitely included in the wording of the sub-section 'every place at which any person has at any time to work.' The sub-section, however, also says 'so far as is reasonably practicable,' and these words have been the subject of several High Court decisions. The interpretation at present seems to be that it is not usually practicable to provide a safe means of access for a workman whose intentions or whose precise whereabouts are not known to the occupier, so that he is only liable if he actually knows, or possibly should know, the exact place where the workman has to work.

This opinion also applies to the provisions of Section 26 (2), which require the occupier to provide means, by fencing or otherwise, to ensure the safety of a person working at a place where he is liable to fall a distance of more than 10 ft., unless secure foothold, and where necessary secure handhold, is provided.

It may be appropriate at this stage to mention the requirements of Section 5 of the Act, that effective provision must be made to secure and maintain adequate and suitable lighting in every part of the factory in which persons are working or passing. This Section appears in Part 1 of the Act, which deals with health, and it is therefore doubtful whether it was there included to deal with safety, but the absence of adequate lighting would certainly affect the safety of the access provided in pursuance of Section 26 (1).

Dangerous fumes and dusts

The provisions of Section 27 detailing the precautions necessary in places where dangerous fumes are liable to be present, and of Section 28 which deals with explosive or inflammable dust, gas, vapour or substance, are of particular importance to the chemical engineer and accidents to contractor's workmen, if caused by a breach of the requirements, would be the responsibility of the factory occupier. With regard to Section 27, outside contractors are often called in to clean vats or tanks which have contained dangerous fumes, and the precautions laid down in the Section should be strictly observed. Similarly, contractors frequently have to open parts of plant containing explosive or inflammable gas under pressure, or carry out repairs by welding, brazing or soldering and the factory occupier is in law responsible for seeing that the precautions laid down in Section 28 (3) and (4) are observed. Attention is also drawn to the provisions of Section 29 (3) requiring a boiler, which is one of a range, to be isolated when any person is allowed to enter, in order to prevent the ingress of steam or hot water from another boiler.

Under Section 64 (1) of the Act the occupier is required to report to H.M. Inspector of Factories for the district any accident occurring in a factory which causes loss of life and which disables any person employed therein for more than three days from earning full wages at the work at which he was employed. Section 64 (3) states that 'where any accident to which this Section applies occurs to a person employed, and the occupier of the factory is not the actual employer of the person killed or injured, the actual employer shall, if he fails to report the accident to the occupier immediately, be guilty of an offence and liable to a fine not exceeding £5.' It would be as well for these requirements to be made clear to the contractor, as the prime duty of reporting any accident is on the occupier and he is contravening the provisions of Section 64 (1) by failing to do so, even though the contractor may be guilty of a contravention of Section 64 (3). The same requirements apply in respect of Section 65 (reporting of certain dangerous occurrences involving no injury) and Section 66 (reporting of cases of certain types of industrial disease).

Section 88 of the Act states that restrictions on the hours of employment of young persons laid down in earlier sections shall not apply to male young persons employed as part of the regular maintenance staff of a factory, or by a contractor, in repairing any part of the factory or any machinery or plant therein. This relaxation has been modified by the Building and Engineering Construction (Young Persons) Order, 1942,[4] which restricts the hours of young persons employed in building operations and certain specified works of engineering construction. The Order, however, clearly lays the obligation of compliance wholly on the actual employer of the young persons, so that the occupier has no responsibility in respect of the hours of work of any such persons employed by a contractor.

Special regulations

In the Building (Safety, Health and Welfare) Special Regulations, 1948,[5] the duty of compliance is by Regulation 4 placed on 'the contractor and employer of workmen who is undertaking any of the operations to which these Regulations apply,' *i.e.* the construction, structural alteration, repair or maintenance of a building (including re-pointing, redecoration and external cleaning of the structure), the demolition of a building and the preparation for, and laying the foundation of, an intended building. It would appear, therefore, that the occupier of a factory on the premises of which any of these processes are being carried out by a contractor would not be responsible for any accident to a contractor's workman due to a breach of the Building Regulations, the full responsibility being on the man's own employer. The occupier, however, would, as already pointed out, be liable for an accident to a builder's workman due to a breach on his (the occupier's) part of the Factories Act.

So far as all other codes of special regulations are concerned, it would appear that the factory occupier is entirely responsible for their observance and an accident to a workman, even though he were not in the employ of the occupier, would nevertheless be his responsibility. Particular cases of such accidents are where the employees of electrical contractors have been killed or injured through breaches of the Electricity Regulations, 1908.[6] In the preamble to these regulations under the heading 'Duties' is the following:

'It shall be the duty of the occupier to comply with these Regulations. And it shall be the duty of all agents, workmen and persons employed to conduct their work in accordance with these Regulations.'

It would seem, therefore, that there is to a certain extent a dual responsibility between the occupier and the contractor,

but, as already stated, it would be necessary for the occupier, in the event of an accident to a contractor's workman, to prove that he had exercised 'due diligence' and taken every precaution to ensure that the regulations were observed. If he could prove that the contractor or his foreman had deliberately tampered with the safety arrangements or deliberately ignored his instructions, the liability both as regards breach of statute and claims for personal injury would probably be transferred to the contractor.

Outside workers are frequently employed in connection with the use of locomotives and waggons on lines and sidings on factory premises, and the Locomotive Regulations, 1906,[7] apply to such processes. These regulations require point rods, signal wires and ground levers' working points to be in safe positions; the provision by the occupier of coupling poles, sprags and scotches; adequate recesses at fixed intervals where materials are stacked within 3 ft. of a line of rails; and stringent precautions where locomotives are pushing, instead of pulling, more than one waggon. An accident due to a breach of any regulation to any person who has lawful business on the premises would be the responsibility of the occupier, so that the requirements will repay careful study.

Chemical Works Regulations

The Chemical Works Regulations, 1922,[8] affect outside workers in one or two respects only. An outsider might possibly be allowed to enter a closed vessel without the precautions laid down in Regulations 7 and 8 having been taken, *e.g.* for purposes of rescue, and outside contractors are occasionally employed to clean tanks, stills and other vessels on which there is a danger of the evolution of arseniuretted hydrogen, in which case Regulation 9 would apply. Accidents to men delivering strong acids or dangerous corrosive liquids, if they occur on the factory premises, might involve the occupier in damages if a breach of Regulation 10 (provision of means of drenching, eyewash bottles, goggles and gloves) could be proved.

COMMON LAW LIABILITY OTHER THAN STATUTORY

In general it may be said that the obligations of any employer, apart from his statutory duties, are to provide and maintain proper machinery, plant, appliances and works; to take 'reasonable care,' which includes the selection of properly skilled persons to manage and superintend the business; and to provide a proper system of working. Applying these principles to cases where work is being done by contractors on factory premises for the benefit of the factory occupier, the latter would appear to be liable in respect of (*a*) machinery, appliances or tackle which they may have provided for the use of the contractor's workmen, (*b*) the condition of the premises and (*c*) dangerous activities carried out in the course of their business.

Although the direct employer is under an obligation to establish a safe system of work for his own employees, he is not required in law to do so in respect of other workers on his premises, even though the work they are doing is in his interest or for his benefit.

The liabilities mentioned above will now be discussed seriatim:

(a) Machinery, appliances, etc., provided by the occupier

The following opinion given by a legal authority sums up the position as follows:

'The owner of a machine which he lends out for hire is under an obligation to ascertain that it is reasonably fit and suitable for the purpose for which it is expressly lent out or for which, from its character, the owner must be aware that it is intended to be used. There is thus a sort of implied warranty that the machine is as fit and suitable for its purpose as reasonable care and skill can make it. The consequence is that, if any loss or damage is caused to the hirer by some defect of which the owner was aware, or ought to have been aware, in the fitness and suitability of the machine, the owner would be liable for the results of his lack of care in this respect, and not only the immediate results but any further consequences which may reasonably be supposed to have been within the contemplation of both parties. There are at least two reported cases in which a defendant hired out tackle to plaintiffs whose workmen were injured by the unfitness of the tackle. The plaintiffs, *i.e.* the people who had hired the tackle, had to compensate their workmen for the injury suffered by the workmen, but they recovered from the defendants as owners of the tackle the damages they had had to pay their employees.'

It is therefore suggested that, when machinery is hired out by the factory occupier to the contractor, the latter should be required to sign a form of indemnity on the following lines:

INDEMNITY FOR HIRE OF PLANT

In consideration of the loan by ..... (*occupier's name*) of plant to be used by..... (*contractor's name*) we hereby agree to be liable for any damage or loss of life or personal injury occasioned by or arising out of the use or loan of the said plant by our workers and to indemnify ..... (*occupier's name*) against all claims, demands and costs in respect thereof.

Dated this ..... day of .....19..

Signed .....

Witnessed .....

The document should be signed over a 6d. stamp by a representative of the contractors, on their behalf.

(b) The condition of the premises

The term 'premises' includes places and structures of all kinds upon which any person may be invited to come, including scaffolds and staging, although these may alternatively be regarded as 'plant.' The condition of the premises is always the responsibility of the occupier, but the degree of responsibility depends on the type of visitor who is injured after he has entered the premises. The three types of visitors recognised by law, and the occupier's responsibility towards each type, are as follows:

1. **The trespasser,** *i.e.* a person who has received no permission from the occupier to enter the premises. The occupier has no duty to safeguard the trespasser, except that he must not injure him intentionally. He may also be liable for damages if he starts a 'dangerous activity' with the knowledge that the trespasser is in the vicinity and may be injured.

Three typical cases of such 'dangerous activities' which came before the courts may be quoted. In each case it was held that the occupier must take reasonable care for the safety of the trespasser.

(i) The occupier was shunting railway trucks with the knowledge that trespassers were in the vicinity.

(ii) A haulage machine was started up with the knowledge that children had been climbing over it a few moments before.

(iii) A tree was felled when children were known to be in the vicinity.

Trespassers, however, have failed to recover damages for coming in contact with moving machinery and high-tension electrical installations. It is clear, therefore, that, so far as trespassers are concerned, even if there is a source of grave danger on the land the occupier is not bound to fence it or to affix warning notices.

2. **The licensee,** *i.e.* the person who enters the premises for his own purposes which do not concern the occupier but to whose entry no objection is taken. A typical example is where a workman uses a 'short cut' over an occupier's premises to get to his own place of work, or where he uses a lift or a staircase in a building on the premises of another tenant to reach his own employer's premises. Such use of premises is in law regarded as a gift by the occupier to the user. It was ruled as long ago as 1867 that 'the principle of the law as to gifts is that the giver is not responsible for damage resulting from the insecurity of the thing, unless he knew of its evil character at the time and omitted to caution the donee . . . If I dedicate a way to the public which is full of ruts and holes the public must take it as it is.'

Lord Sumner, in the case of Mersey Docks & Harbour Board *v.* Procter,[9] explained this in the following words:

'A licensee takes premises . . . just as he finds them. The one exception to this is that . . . the occupier must not lay a trap for him or expose him to a danger not obvious nor to be expected there in the circumstances. If the danger is obvious the licensee must look out for himself. The occupier must act with reasonable

diligence to prevent his premises from misleading or entrapping a licensee.'

The liability of an occupier for a 'danger not obvious nor to be expected there in the circumstances' includes concealed or hidden dangers on the premises of which he knows or should know. Examples of such dangers are openings in floors covered by loose boards, sacking or asbestos sheets; defective or missing rungs in ladders; and door openings in a wall with no platform or railing outside to prevent the fall of a person.

3. **The invitee**, *i.e.* the person who enters the premises on the invitation of the occupier including persons who are to work for him or for his benefit. Contractor's employees are therefore invariably invitees, as are persons who enter to inspect plant or electrical and other installations.

The duty of the occupier towards the invitee has been summarised in one leading case as follows:

'We consider it settled law that he (the invitee), using reasonable care on his part for his own safety, is entitled to expect that the occupier shall on his part use reasonable care to prevent damage from unusual danger which he knows or ought to know; and that, where there is evidence of neglect, the question whether such reasonable care has been taken, by notice, lighting, guarding or otherwise, and whether there was contributory negligence by the sufferer, must be determined by a jury as a matter of fact.'

An indication of what is an 'unusual danger' was given by the House of Lords in the case of London Graving Docks Ltd. *v.* Horton,[10] where it was held that the normal occupation of the invitee must be taken into account in deciding whether a danger is 'unusual' or not. It was stated that 'a tall chimney is not an unusual danger for a steeplejack, though it would be for a motor mechanic.' In another case it was decided that 'a loose window is not an unusual danger to a window cleaner since such risks are frequently encountered in his type of work' (Christmas *v.* General Cleaning Contractors Ltd.).[11]

It will be noticed that the above judgment also makes the occupier responsible for unusual danger 'which he knows or ought to know.' It was held, however, in the case of Woodman *v.* Richardson & Concrete Ltd. that the occupier was not liable for injuries caused by a defective ladder which had been brought out from a rubbish dump by an unknown person. This particular ladder had been condemned and the occupier was quite unaware that it had been brought back.

The occupier is responsible for the safety of the invitee only in such places where he (the invitee) may reasonably be expected to go to carry out his work. If he goes anywhere else the invitee becomes a trespasser, or possibly a licensee, and the occupier's duty is limited as outlined under (1) and (2) above.

(c) Dangerous activities

The occupier is liable if his own employees, in the course of their work, do not take reasonable care to avoid accidents to contractor's workmen due to dangerous activities such as (*a*) handling objects liable to fall from a height, *e.g.* loads suspended from cranes, and felling of trees and (*b*) driving railway engines, cranes and other vehicles. On a highway an injured workman has the same rights as other members of the public, but on factory premises the driver must exercise the same reasonable care as he would on the highway if he has reason to suppose that other persons may be in the vicinity.

Duties of contractors to each other

Where more than one firm of contractors are working on the same premises they are responsible to each other for injuries caused by negligence, either in the method of working or by the workers' own acts or omissions. Their liability includes injury caused by negligence resulting in dangerous conditions on the premises. In one case ship repairers' workmen left a hatch uncovered and in darkness, and a stevedore fell down the hatch and was injured. The House of Lords held that the ship repairers were liable for the accident at common law, quite apart from the duties under the Docks Regulations,[13] because their employees had worked at the hatch and left it in an unsafe condition.

REFERENCES

[1] *All England Law Reports*, 1949, **1**, 532.
[2] *Ibid.*, 1949, **1**, 540.
[3] *Ibid.*, 1947, **2**, 324.
[4] S.R. & O., 1942, No. 2269.
[5] S.I., 1948, No. 1145.
[6] S.R. & O., 1908, No. 1312.
[7] *Ibid.*, 1906, No. 679.
[8] *Ibid.*, 1922, No. 731.
[9] *Times Law Reports*, 1923, **39**, 275.
[10] *All England Law Reports*, 1951, **2**, 1.
[11] *Ibid.*, 1952, **1**, 39.
[12] *Ibid.*, 1937, **3**, 866.
[13] S.R. & O., 1934, No. 279.

Recent publications

Fish meal and oil plant. List No. 47 issued by Rose, Downs & Thompson Ltd. is a 12-page illustrated pamphlet which describes some of the equipment designed and manufactured by the company for the fish meal and oil industry. Among newer equipment to be noted are the unit construction driers and cookers, which have been introduced to simplify plant expansion. There is a world-wide demand for high-protein meals, and this publication describes, with the aid of simplified flow diagrams, methods of production from both white and oily fish. Brief reference is also made to whale plant, a sphere in which the company has had a long experience.

Instruments for industry. Electronic equipment for industry is described in an illustrated pamphlet by Marconi Instruments Ltd. This is a 28-page abstract from the company's catalogue and it is divided into three main sections: *p*H measurement, moisture measurement and industrial X-ray apparatus. Design details and specifications are given for each instrument. The X-ray apparatus provides a non-destructive method of verifying that welded or cast components are free from internal flaws; time and money may often be saved by radiographic inspection before machining. The installation featured in the catalogue has a range of tube movements and generator outputs wide enough to make it suitable for a variety of engineering applications.

High-vacuum equipment. Several new publications have been published by W. Edwards & Co. (London) Ltd. An eight-page pamphlet illustrates and describes in detail the complete range of *Speedivac* rotary pumps, including the two latest additions to the range, displacing 5 and 15 cu.ft./min. respectively. Another pamphlet deals with moisture and mercury vapour traps. Three models are shown which can be fitted to pumps, whilst others are suitable for placing in the vacuum line. The technique of vacuum coating, notes on some of its present-day uses and the complete range of plant made by the firm for both evaporation and sputtering are described in a third eight-page pamphlet. Each plant is illustrated separately, with the various jig arrangements, and a specification table shows their technical characteristics and pumping-down times. Finally, the company's whole series of 'Vacuum Notes' advertisements has been reprinted and bound in booklet form. The most common problems encountered in the use of vacuum are described with the aid of diagrams.

Correspondence

Indian dye manufacturers

To the Editor.

Dear Sir.—I refer to a news item in your issue of February 1953 on p. 59, regarding dye production in India. In this connection I have to point out that there are other dye producers in India besides Atul Products Ltd., whom you have mentioned as India's sole dye producer. These other producers have been producing stabilised azoics, one of them the Associated Research Laboratories, from as early as 1940-41. Since 1948 they have also been producing solubilised vats, stabilised azoics of Rapidogen types and oil-soluble dyes, etc. This is just for your correct information and record.

T. R. SATHE,
Manager, Associated Research Laboratories
Bhatgar, Poona,
India.

Plant and Equipment

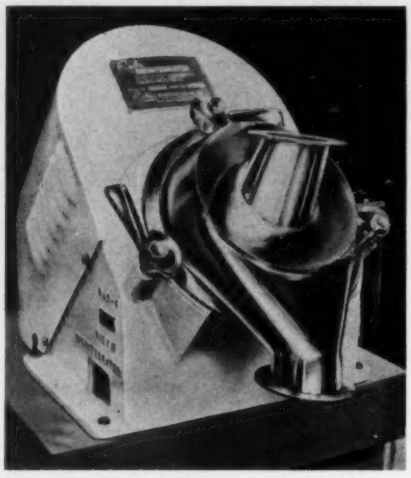
Angle disintegrator

A new laboratory angle disintegrator is claimed to be able to handle wet, moist or dry materials without clogging, and to give continuous separation of disintegrator-resistant material from the primary product. George Scott & Son (London) Ltd. have recently concluded an agreement with the Rietz Manufacturing Co. of California covering the manufacture and sale of the machine, together with the Rietz pre-breakers and *Thermascrews*, in Britain and the Commonwealth.

The disintegrator has an inclined rotor shaft carrying a series of fixed hammers operating inside a 360° screen. It has quickly removable feed spouts and two discharge openings—one for disintegrated material and the other for disintegration-resistant material. The drive is from a two-speed motor, through a two-speed centre belt drive, giving four speeds for the rotor. Screens and beaters are quickly and easily removable for cleaning and maintenance.

There is a range of five sizes, the power consumption for the smallest being ½ to 1½ h.p., and for the complete range ½ to 30 h.p.

The same principles are incorporated in a vertical rotor range of machines utilising powers ranging from 5 to 400 h.p. With the Rietz pre-breaker these machines are capable of handling large material, including complete animal and fish carcases, frozen meat block, green bones, wood, plastics, fruit, animal and vegetable waste material.

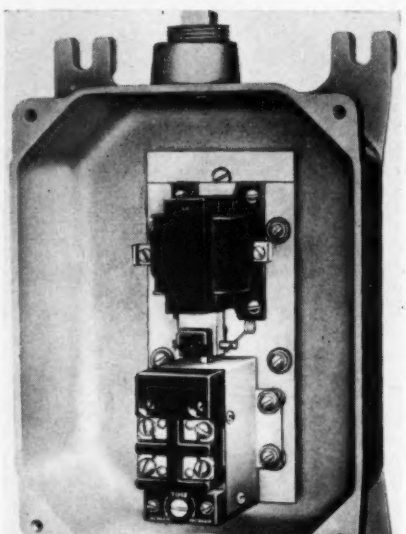


Laboratory angle disintegrator, capable of handling a variety of wet, moist or dry materials.

Magnetic swarf recovery

The present high cost of non-ferrous materials renders it economical to reclaim as much swarf as possible from machine-shop operations. In the case of firms operating their own foundries it is essential that this swarf is free of iron, while in the case of those who sell swarf as scrap its value is greatly increased if it is free from iron contamination.

The iron-contaminated swarf is readily picked up in the machine shop either during machining or during collection of the swarf. A magnetic separator of the drum type is frequently employed to separate the swarf from the iron. This type of machine has horizontal magnet poles so that, as the swarf is fed on to the drum, the iron particles form up in rows across the drum. During the rotation of the drum the non-ferrous material passes forward, but the magnetised particles tend to cling on the drum along the line of the magnet poles. A number of ribs are fitted to the drum and as these move forward the iron is pushed away from the magnetic pole and, in jumping to the next magnet bar, turns completely over. By this means any non-ferrous material which was trapped is released. In practice a drum would normally have six sets of magnet bars, so that by the time the swarf has passed over the drum it provides a very clean non-ferrous product, while the extracted iron is equally free of non-ferrous material.



Pneumatic time-delay relay.

Drum-type magnetic separators have been on the market in various forms for a long time. A disadvantage has been the high feeding height and the necessity of having cams at the back of the feed tray to jolt down the feed, which does not flow freely. This has resulted in excessive noise and continual wear on the cam plates.

A new machine, the *Magco* feeder, is claimed to eliminate these disadvantages. There are no moving parts with consequent wear, and lubrication is not necessary. Feeding height is reduced to 40 in. and there is little noise. There is a range of drum widths from 6 to 36 in. with a 14-in. diameter permanent magnetic drum. A similar machine is available with vertical pole and electro-magnetic drums of any size or width to suit the required capacity. The standard vibrating feeder is available in sizes of up to 25 or 50 tons/hr. This is a self-contained machine for handling a wide range of products. The hopper accepts the feed at an irregular rate and spreads it evenly over the drum at the appropriate feeding rate. Makers are Magnetic Equipment Co. Ltd.

Electric control for valves and processes

The pneumatic time-delay relay is a single-pole change-over switch in which 'make' or 'break' timing can be set to operate over the range of ⅛ to 180 sec. It comprises a compact pneumatic system and a robust solenoid and is mounted in a fully-tropicalised case of cast aluminium. It is used for controlling accelerating contactors of motor starters, timing the opening and closing of valves in refrigeration plant, controlling sequential process operations and for the delayed starting of loop-circuit electrical equipment, thereby eliminating high mass-starting current.

The pneumatic system, which is actuated by the solenoid, consists of a spring-loaded bellows of synthetic rubber and an adjustable air valve for controlling the rate of expansion. The makers (Electro Methods Ltd.) claim that this system affords far greater accuracy over a considerably wider timing-range than is possible with the conventional dash-pot system.

The solenoid is a rigidly constructed assembly of low-loss silicon-iron laminations, with a fully impregnated coil and shaded-pole plunger.

With the solenoid de-energised, the solenoid plunger is withdrawn from the coil by spring loading and, simultaneously, the bellows are compressed. Therefore, on energising the solenoid, its plunger is instantaneously pulled back into the coil, thereby permitting the bellows to expand under its own spring tension. The duration of the expansion time is predetermined by regulating the air valve. At the conclusion of the expansion cycle a snap-action 'double-break and make' switch is automatically engaged and held until such time as the solenoid is de-energised, whereupon the switch contacts snap over and the solenoid plunger is withdrawn from the coil to recompress the bellows.

For further details of plant and equipment please write to the Enquiry Bureau, 9 Eden Street, London, N.W.1.

World News

GREAT BRITAIN

Pollution Mission visits chemical factories

Five chemical works in England and Wales were recently inspected by an intra-European mission which is studying water- and air-pollution problems of the European chemical industries. The mission, which is organised by the O.E.E.C., numbers some 20 representatives of research institutes, public health authorities, water authorities, industrial organisations and other bodies drawn from all over Europe. They had previously visited Sweden, Germany, Holland and Belgium and, after leaving the U.K., went on to France. They will eventually report on the best European practice, and it may subsequently be decided to organise a mission to study the problem in the U.S.A.

At the Ruabon, north Wales, works of Monsanto Chemicals Ltd., which is located in an area of noted beauty in the valley of the River Dee, the mission was taken on a detailed tour of inspection of the recently constructed biological effluent purification plant. This plant, opened in June 1952, is believed to be the first large-scale application in the U.K. of this method of treatment of chemical waste liquors of non-biological origin. At the time of the formal opening, Monsanto had, since the initiation of its protective measures, spent upwards of £600,000 on all aspects of its effluent purification programme. The work still continues and substantial extensions to the biological purification plant have been brought into operation during the past year.

The Dagenham, Essex, works of May & Baker Ltd. was also visited and the plants for the treatment of effluent liquors and gases were inspected. In addition, the mission visited the works of Courtaulds Ltd. (Preston), British Enka Ltd. (Aintree) and Shell (Stanlow). The chairman of the mission is Mr. M. D. Bone, of I.C.I. Other U.K. representatives are Dr. E. A. B. Birse, of the Department of Health for Scotland, and Dr. J. S. Wilson, of Monsanto.

Midlands gas works enlarged

Flexibility is an outstanding feature of the West Midlands Gas Board's newly-enlarged works at Swan Village, near Birmingham. Without altering the total quantity of gas made, annual coal requirements can be varied between 180,000 and 138,000 tons, with corresponding variations in coke available for sale of between 61,000 and 34,000 tons, based on a load factor of 83%.

The new carbonising plant, built on a site adjoining the old works, comprises 64 continuous vertical retorts heated by four mechanical producers, with a fifth acting as a standby. It can produce 8½ million cu.ft./day of coal gas. In addition, a new 3-million-cu.ft./day water-gas machine has been installed in an extension of the water-gas house at the old works. The water gas is piped in the crude state to the new works where it is metered and then purified with the coal gas. Together the old and new works have a maximum daily gas output of 21 million cu. ft.

Oil refinery to make microwaxes

A plant nearing completion at Anglo-Iranian's Llandarcy refinery will manufacture microcrystalline waxes. These materials, which are more flexible and ductile than normal paraffin waxes and can be produced with much higher melting points, have hitherto been imported from the U.S. They are used for coating papers and for polishes, etc.

New grades of carbon black to be made

Arrangements have been made for the manufacture in the United Kingdom of Kosmos and Dixie grades of furnace carbon black previously produced only in the U.S.A. This was announced by Mr. Oscar Nelson, president of United Carbon Co. Inc., Charleston, West Virginia, on the eve of his departure from Europe at the conclusion of a prolonged visit.

A long-term agreement has been reached whereby United Carbon Co. Inc. is making its technical knowledge and engineering experience available to United Carbon Black Ltd., Swansea, for the purpose of establishing standards and ensuring control of quality.

Mr. Nelson's visit followed many months of exhaustive studies by the technical staff of United Carbon Co. Inc., both at Swansea and in their engineering department in America. As a result of these studies, modifications of existing plant and processes are already in progress and plans have been made for the construction of additional capacity at Swansea.

The modifications now in progress will result in the production of a general-purpose furnace black to be marketed as Dixie 45 and Kosmos 45 by the selling agents of United Carbon Co. Inc., namely Anchor Chemical Co. Ltd. and Chance & Hunt (a section of Imperial Chemical Industries Ltd.). It is planned to produce other types of furnace black similar to the grades manufactured by United Carbon Co. Inc. in the U.S.A.

These arrangements will enable customers of United Carbon Co. Inc. to obtain prompt delivery of high-quality furnace blacks against payment in sterling.

New telephone numbers

The telephone numbers of the Gauge and Tool Makers' Association has been changed to Hyde Park 3451/2.

NEW APPOINTMENTS

★ **Mr. W. J. Deverall** has been appointed a director of Joseph Crosfield & Sons Ltd. and of William Gossage & Sons Ltd. Mr. Deverall, who is 47, joined Crosfield's technical staff after the war and was appointed works manager in 1946. Recently he was appointed a member of the Association of British Chemical Manufacturers' Manchester Area Committee on 'Productivity in the Heavy Chemicals Industry.'

★ **Mr. S. Yates-Dutton** has been appointed chemical sales manager of Crosfield's in succession to **Mr. A. C. H. Cairns** who, as reported last month, has joined the board.

★ **Sir Roger Duncalfe** has been elected president of the British Standards Institution. His appointment was proposed by Lord Waverley, whose three-year term of office had ended in accordance with the B.S.I. constitution. Sir Roger is chairman of British Glues & Chemicals Ltd. and has been closely identified with standards work and the B.S.I. for more than 20 years. He has been successively chairman of technical committees engaged on standards projects, chairman of the Chemical Divisional Council and of the Institution's Finance Committee and General Council, and more recently its vice-president. He was knighted for his outstanding contributions to industrial standardisation at the time of the B.S.I. Golden Jubilee in 1951.

Although he has devoted so much time and energy to this specialised activity, Sir Roger has also undertaken much work in other directions on behalf of industry. He is president of his own industry's organisation, the Federation of Gelatine & Glue Manufacturers; past chairman and vice-president of the Association of British Chemical Manufacturers; and his long service to the Federation of British Industries is marked by the fact that he holds the office of vice-president and is also chairman of the Federation's Technical Legislation Committee.

★ **Mr. C. F. Merriam,** chairman of the British Xylonite Co., has been elected the first president of the British Plastics Federation, which was founded in 1933.

★ **Mr. Stephen F. Burman,** M.B.E., has been appointed a director of Imperial Chemical Industries Ltd. He will act as a non-executive director. Mr. Burman is managing director of Burman & Sons Ltd., Birmingham, production engineers, and a director of Joseph Lucas (Industries) Ltd., W. & T. Avery Ltd., Serck Radiators Ltd. and other companies. He is prominent in Birmingham business circles, being a past president of the Chamber of Commerce, a governor of the University of Birmingham and vice-chairman of the Regional Board for Industry.

★ **Mr. E. L. Streatfield,** B.Sc., F.R.I.C., M.I.Chem.E., has taken charge of the

London office of Houseman & Thompson Ltd. at 152 Haverstock Hill, N.W.3 (telephone Primrose 7145). Mr. Streatfield contributes to our 'Chemical Engineering Reviews' series on the subject of filtration. He was formerly a director of Filtrators Ltd., and is chairman of the London section of the Society of Chemical Industry.

Obituary

We announce with regret the death of Lt.-Col. W. A. Vignoles, D.S.O., M.I.E.E., a director of Evershed & Vignoles Ltd. He was born in 1874 and received his technical education at Finsbury Technical College. In 1928 he was appointed Director and Secretary of the Electrical Development Association, from which appointment he resigned in 1931 to join the board of Evershed & Vignoles as joint managing director. In 1941, owing to ill health, he resigned the position of managing director, but still held a seat on the board.

Nickel restrictions removed

All restrictions on the use of nickel were removed on November 6. The Minister of Supply has withdrawn the Alloy Steel Directions restricting the use of nickel in the manufacture of alloy steels.

Suction handling of phosphate rock

The first consignment of powdered phosphate rock recently delivered to the new Albright & Wilson phosphorus factory at Portishead, near Bristol, was unloaded from the Panamanian ship *Areti* by suction gear. This is the first time phosphate rock had been handled in this manner, which is much cleaner than the old methods. The sand-like ore is unloaded by two mobile suction pumps, which can operate in either two holds or two vessels. The rock is carried by band conveyor to a bank of eight 100-ft.-high storage silos which have a capacity of 25,000 tons.

The factory, which will be the largest phosphorus-producing unit in the country, will be coming into production at the end of the year. When on full capacity it will absorb cargoes like the *Areti*'s 5,300 tons at the rate of one a week. Portishead was chosen for the site of the factory because of its deep-water harbour. It has the second highest rise of tide in the world, and this enables ocean-going freighters to tie up at the dock and unload straight into the silos, avoiding any further handling or transport.

ITALY

Cement factory for S. Italy

A new cement factory with a production capacity of more than 100 tons/day is to be built at Galatina, in the province of Lecce. It will cost about 720 million lire, of which the Cassa del Mezzogiorno (Fund for the South) is to provide 430 million. The factory is expected to make a substantial contribution towards reducing the present shortage of cement in the Puglie region.

Powdered phosphate rock being unloaded from a ship by suction gear at Albright & Wilson's new Portishead factory.

BELGIUM

Big metal-treatment plant opened

What is claimed to be the largest metal pre-treatment and reconditioning plant in the world was opened in a factory near Antwerp last month. Military vehicles and equipment will be treated in it.

Basically the plant comprises three immersion tanks for (1) degreasing and paint stripping, (2) heavy scale removal and (3) rust removal, rust proofing and paint bonding. The size of the first tank is 29 ft. × 12 ft. × 9 ft., with a normal working capacity of 16,450 gal. of solution. Tanks 2 and 3 are each 30 ft. × 12 ft. × 10 ft., with working capacities of 15,250 gal. of solution. To this must be added a water-jacket capacity of 5,550 gal., giving a total capacity of 20,800 gal. The first tank is steam-heated through coils and the other two by means of steam-heated water jackets.

Between tanks 1 and 2 is a brick pit equipped for power rinsing, in which components are rinsed after degreasing and scale removal. Components, both new and those requiring renovation and maintenance, are delivered from tank to tank by power-operated cranes capable of handling up to 25 tons weight.

This plant, valued at approximately £50,000, has been designed, erected and delivered by Jenolite Ltd., London, who also manufacture the pre-treatment chemicals used on the project.

GERMANY

'Terylene' production licensed

Two companies are to produce *Terylene* polyester fibre in Western Germany under licence from I.C.I. They are Farbwerke Hoechst A.G., of Frankfurt, and Vereinigte Glanzstoff-Fabriken A.G., of Wuppertal-Elberfeld.

Western Germany thus becomes the third European country to take up production of this synthetic fibre. As was reported in the October and November issues of CHEMICAL & PROCESS ENGINEERING, I.C.I. have already licensed Montecatini, of Milan, to make *Terylene* in Italy, while Société Rhodiaceta, of Lyons, will make it in France.

I.C.I. investment in *Terylene* in the U.K. is now nearly £20 million.

Western Zone's chemical output

Sales of West German chemical products during the first eight months of 1953 reached almost 7,000 million marks, an increase of 10% over the corresponding period of 1952, according to the West German Chemical Industries Association. Turnover in August 1953 totalled 896.8 million marks.

Exports rose in August to 205 million marks from 196 million in July. This favourable trend was, however, attributed largely to seasonal exports to overseas countries, especially of potash fertilisers. There was also an increase in the export of ferrous alloys, which went mainly to the U.S., while exports of lacquers, coal-tar dyes, chemical fibres and photochemical products declined.

Exports to overseas countries increased in the first half of 1953 by 50% to 440 million marks over the first half of 1952. They amounted to 42% of the total.

Chemical products accounted for 13.6% of West Germany's exports in August, compared with 12.4% in the first half of 1953 and 10.5% in 1952.

FINLAND

Cellulose acetate production

Finland is to begin producing cellulose acetate on a commercial basis in the near future, after a period of laboratory and plant research, it is reported in Helsinki. Imports of this material by member companies of the Finnish Plastics Association in 1952 totalled 150 tons.

The industry is also striving to increase production of other types of plastics from domestic raw materials, particularly phenolic resins, but large quantities of major basic materials still have to be imported.

GREECE

German funds for industrial projects

A team of experts from Germany is at present in Greece in connection with a plan for the exploitation of the lignite mines at Ptolemais, in western Macedonia, and the building of a briquette factory, a thermal power station, a nitrogen plant, a blast furnace and also a nickel plant in southern

Greece. According to a press report, a Greek/German company has been formed to carry out these projects. The Greeks are said to be putting up one-half of the total cost of between 43 and 45 million dollars and the Germans to have undertaken to establish credits for the balance of 20 million dollars.

TURKEY

Cement factories planned

Foreign as well as domestic private capital will be invited to bid for the construction of each of 38 new cement factories which are being planned by the government.

Bids for 20 of the new factories will be solicited in the near future. The remaining 18 plants will be built in the next few years.

INDIA

Synthetic petrol plant scheme revived

The Government of India has decided to revive a proposal to set up a synthetic petrol plant in the country. A production ministry spokesman said that the previous proposal was dropped because of the financial outlay involved, but it had now been decided that, because of the strategic importance of petroleum products, the government must take a new view of the project. At present, plans were under way for establishing refineries in India, but, the spokesman said, the country wanted to have a petroleum industry which would not be dependent on imported crude oil.

Oil in Assam

The most intensive programme of oil exploration yet undertaken in India is to be carried out in the next few months in the Brahmaputra Valley, Assam, according to a statement of the Assam Oil Co. Oil was struck recently near the main Digboi oilfield and near the southern edge of the alluvial plain in a well drilled to a depth of over 10,000 ft. In view of this discovery, a new assessment is to be made of the valley's petroleum possibilities.

The forthcoming survey will be of three kinds—seismic, gravity and aeromagnetic—made simultaneously. It will cover more than 5,000 sq. miles in all.

Hopes of finding rich oil deposits in Bengal, which adjoins Assam, were reported in CHEMICAL & PROCESS ENGINEERING, March (p. 90). It was also reported that the Standard Oil Co. had planned to spend Rs. 100 million in the next five years on drilling oil.

BRAZIL

Equipment needed by new fertiliser company

The exploitation of the apatite (calcium phosphate) reserves in the Araxa area, reported in our November issue (p. 371), is to be undertaken by a company largely owned by the government of the state of Minas Geraes. It will be known as the Fertilizante Minas Geraes S.A., and it is believed that it will require quarrying equipment, such as air compressors and rock drills, capable of quarrying 200 to 300 tons/day of apatite. The type of equipment required is now being studied by the Instituto de Tecnologia, at Belo Horizonte. The apatite is said to be about as hard as ordinary limestone.

The company is also reported to be interested in setting up a mill with a capacity of 100 tons/day to grind alkali rock (of limestone hardness) at Pocos de Caldas, in the state of Minas Geraes. In addition, an overhead cable conveyor system between 3 and 4 km. in length will probably be required.

No tenders for the supply of equipment have yet been invited, but firms interested in supplying suitable equipment and who wish to make contact with the Fertilizante Minas Geraes S.A. are advised to do so through the British Vice-Consul (Mr. H. V. Walter) at Belo Horizonte.

The apatite deposits are calculated to amount to 100 million tons, but no doubt this includes low-grade ore. The average of samples taken gives a content of 30% phosphates, with impurities of 41% calcite, 13% limonite and small quantities of carbon, aluminium, etc.

The Leonard Hill Technical Group — December

Manufacturing Chemist—Manufacture of Heliotropin; Redox Indicators; Synthesis of Adrenocortical Hormones; Ampholytic Detergents; Chemical Anniversaries of 1954; New Aspirin Plant; Progress Reports on Chemotherapy and Antibiotics.

Food Manufacture—Chelsea Flour Mills; Processing Vegetables in the U.S.A., 2; American Flavours for Soft Drinks.

Paint Manufacture—The Effect of Driers on the Properties of Alkyd Resin Finishes, 4; Paint Technology and the Law, 1; Varnish and Paint Production at the I.C.I. Slough Works, 2; Canadian Raw Materials Report.

Fibres—The Working of Fibres; Sisal Products; Developments in Processing Man-made Continuous Filament Yarns; Instrumentation and Process Control in the Jute Industry.

World Crops—The Work of the Port of London; Agricultural Planning in East Africa; The Reclamation of Land Flooded by Sea Water.

Petroleum—Newer Petroleum Products; Report on the Paris Meeting of the European Association of Exploration Geophysicists, 1953; India's Refinery Project Takes Shape; Measurement of Engine Wear with Radio-isotopes; Petroleum Abstracts.

Atomics—The Outlook for Economic Nuclear Power; Applications of Radioactive Isotopes in the Wool Industry; Medical Research Council's New Accelerators.

Building Digest—Industrial Lighting; The Recently Completed People's Stadium in Budapest.

Muck Shifter—Highway Construction in Northern Rhodesia; Scientific Investigations into the Problem of Road Construction.

PAKISTAN

Cement and fertilisers in Punjab

The Punjab Government has published the text of an agreement with the Pakistan Industrial Development Corporation under which the corporation has acquired 3,500 acres of land at Daudkhel, in Mianwali district, for the erection of cement and fertiliser factories. The agreement provides for the construction of the factories and ancillary buildings, roads, pipelines, godowns and domestic buildings, and stipulates that the corporation shall complete the construction of the factories and other buildings within four years of the date on which they are given possession of the land. It is a condition of the agreement that the corporation should provide technical knowledge and training in the factories to suitable applicants by introducing apprenticeship and similar training schemes.

UNITED STATES

Monsanto's polythene plant

The Monsanto Chemical Co. has selected Texas City, Texas, as the site for its first polythene production plant. Plans for the new unit set initial capacity at about 66 million lb. p.a., with a 50% increase scheduled for 1957. Construction work is already under way.

Dow Chemical's expansion plans

The Dow Chemical Co. intends to spend about $75 million for new plant this year. This will complete an expansion programme totalling about $300 million.

The president of the company said that during 1954 there might be some softening of prices and possibly some decline in dollar value for production, but he did not believe it would exceed 10% in the chemical industry. He expected some setbacks with the older type industrial chemicals and drug intermediates, notably ethylene glycol for anti-freeze. Reduction in synthetic rubber was also in prospect because of reduced prices of natural rubber. On the other hand, petrochemicals would continue to offer good prospects.

Titanium dioxide plant

A new plant is to be built at Savannah, Georgia, for the Calco Chemical Division of American Cyanamid Co., which produces titanium dioxide white pigments for paint, paper, hard floor coverings, ceramics, rubber and plastics. The plant will be built by Chemical Construction Corp., a subsidiary company.

Improved metal processing technique

A simple method of improving both the quenching and tempering action of salt baths in the metal industry has been developed by American Cyanamid Co. Water is added to a nitrate-nitrite bath while it is in a molten state, and this is claimed to result in many advantages, including lower operating temperatures and maintenance of the bath's original

composition for long periods of time below the mixture's boiling point.

The development represents an unusual exception to a widespread safety practice in the metals industry, which calls for water always to be kept away from molten salt baths. A special procedure is adopted to overcome risk.

Varnish and paint oils plant

A vegetable oils processing plant has been opened by the Archer-Daniels-Midland Co. in Los Angeles. The new plant includes a three-storey unit for processing chemically-modified oils, two buildings for production of oleo-resinous varnishes, warehouse, laboratory and office building. In processing oleo-resinous varnishes, materials can be cooked over three open-type fires or in a large stationary closed kettle, all heated by natural gas.

The building which is used to make chemically-modified oils utilises heat, pressure and vacuum equipment. Products made here are classed as heat-bodied oils, copolymer oils and chemically-modified esters. An average batch weighs 15,000 lb. and requires 15 hr. of processing. Two large stainless-steel vessels are used for processing; provision has been made for adding a third tank when volume warrants.

A tank storage farm consisting of 24 tanks, which will hold the equivalent of 400 tank cars of oil, will be used to store drying oils, etc. Five underground tanks will store mineral spirits and special solvents.

CANADA

New cement factory

Production at the Villeneuve plant of the St. Lawrence Cement Co., Canada's newest cement company, is expected to begin in September 1955. Delivery of machinery is expected in mid-1954; Canadian Allis-Chalmers is furnishing most of it, and Brown Boveri (Canada) and Canadian Westinghouse will supply electrical equipment. Installation will begin next year and will be completed in 1955; construction of the mill itself is also due to begin next year.

When it is in full production, the new factory will have an annual capacity of 6 million bags.

MEETINGS

Institution of Chemical Engineers

December 8. ' Problems of Biochemical Engineering,' by J. J. H. Hastings, 5.30 p.m., Geological Society, Burlington House, London, W.1.

December 12. ' Some Aspects of Molecular Distillation,' by G. Burrows, 3 p.m., College of Technology, Sackville Street, Manchester.

December 12. ' Mechanical Shaft Seals for the Chemical Industry,' by T. H. Wood, 3 p.m., The University, Edmund Street, Birmingham.

January 5. ' Some Mechanical Handling Problems in the Chemical Industry,' by J. Johnston, 5.30 p.m., Geological Society, Burlington House, London, W.1.

Graduates' and Students' Section

December 10. ' Heat Transfer to Fine Particles,' by B. Shaw, 6.45 p.m., College of Technology, Sackville Street, Manchester.

December 11. ' The Influence of Alcohol on Chemical Engineering,' by D. C. Freshwater, 6.30 p.m., Caxton Hall, London, S.W.1.

December 16. ' Fluorine Plastics,' by J. Gill, 6.30 p.m., The University, Edmund Street, Birmingham.

December 17. ' The Principles and Applications of Fluidisation,' by J. H. F. Hallet, 7 p.m., Fuel Department, University of Leeds.

Society of Chemical Industry

December 8. ' Some Products of Heat-thickening of Linseed Oil,' by A. J. Seavell and J. J. Sleightholme, 6.30 p.m., the Birmingham and Midland Institute, Paradise Street, Birmingham 1.

December 8. ' Some Problems in the Production and Handling of Milk,' by C. Damoglou, 7.15 p.m., Agriculture Lecture Theatre, Elmwood Avenue, Belfast.

December 11. ' Experiences on a Whaler,' by G. L. Quayle; ' Experiences of a Public Analyst,' by S. Dixon; ' Cement,' by G. M. Kerman; 7 p.m., University College, Cathays Park, Cardiff. Joint meeting with the R.I.C.

December 14. ' The Relation between the Chemical Constitution and the Properties of Polymers,' by R. J. W. Reynolds, 7 p.m., Chemistry Lecture Theatre, The University, Leeds 2. Joint meeting with the Plastics Institute.

December 17. 'Some Aspects of Chemical Engineering,' by H. W. Cremer, 7.30 p.m., Robert Gordon's Technical College, Aberdeen. Joint meeting with the Chemical Society and R.I.C.

Corrosion Group

December 9. ' Electrical Measurements in the Study of Paint Coatings on Metal,' by D. M. Brasher, A. H. Kingsbury and F. Wormwell; ' Mechanism of Protection by Paints with Special Reference to the Action of Basic Pigments,' by J. E. O. Mayne and D. van Rooyen; 6.30 p.m., Chemical Society rooms, Burlington House, Piccadilly, London, W.1. Joint meeting with the Oil and Colour Chemists' Association.

Chemical Engineering Group

December 15. ' Instruments for Quality Control,' by G. C. Eltenton, 5.30 p.m., Geological Society, Burlington House, London, W.1.

Royal Institute of Chemistry

December 8. ' The Manufacture of Antibiotics,' by E. Lester Smith, 6 p.m., Sir John Cass College, Jewry Street, London, E.C.3.

December 10. ' The Breakdown of Macromolecules,' by Prof. H. W. Melville, 7.30 p.m., Midland Hotel, Derby.

Incorporated Plant Engineers

December 8. ' The Use and Application of Mobile Plant,' by J. L. Sturrock, 7.15 p.m., Engineers' Club, Albert Square, Manchester.

December 9. ' The Failure of Metals,' by Prof. J. A. Pope, 7 p.m., Demonstration Theatre, East Midlands Gas Board Showrooms, Parliament Street, Nottingham.

December 16. 'Application of Fuel Oils,' by Peter Wilson, 7 p.m., Scottish Building Centre, 425-427 Sauchiehall Street, Glasgow.

December 17. ' Hydraulics in Industry,' 7.30 p.m., Grosvenor Hotel, Lord Street, Blackburn.

Institute of Fuel

December 9. ' Smoke Abatement,' by G. W. Farquharson, 6.30 p.m., Imperial Hotel, Temple Street, Birmingham.

Institute of Metals

December 11. ' Steels and Other Alloys for High-temperature Applications,' by J. M. Robertson, 7.15 p.m., Cleveland Scientific and Technical Institution, Middlesbrough.

January 5. ' Industrial Methods of Electroplating,' by G. E. Gardam, 7 p.m., Oak Room, Cadena Cafe, Cornmarket Street, Oxford.

Institute of Welding

December 10. ' Gas Welding,' by F. Clark, 7 p.m., the Community Centre, Farnham Road, Slough, Bucks.

December 10. ' Hydrogen *versus* Welding,' by C. L. M. Cottrell, 6.30 p.m., 2 Savoy Hill, London, W.C.2.

December 16. ' The Application of the Self-adjusting Arc,' by P. T. Houldcroft, 7 p.m., Manson House, Portland Place, London, W.1.

Institution of the Rubber Industry

December 8. ' Cyclised Rubber,' by E. P. B. Edwards, 5.30 p.m., Royal Society of Tropical Medicine and Hygiene, 26 Portland Place, London, W.1.

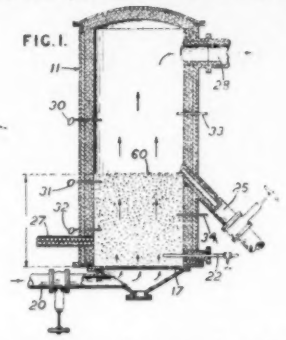
December 14. ' Rubber Processing Equipment,' by J. W. Denson, 6.45 p.m., James Watt Institute, Gt. Charles Street, Birmingham.

Chemical Engineering Invention

MONTHLY SUMMARY OF PATENT CLAIMS

Roasting sulphidic zinc ores

Sulphidic zinc ore is roasted by a fluidised-solids technique at a temperature above that at which zinc sulphate compounds are formed but below that at which sintering occurs, *viz.* 850 to 930°C. As shown, the powdered ore concentrate is



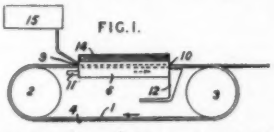
fed by screw 27 into a refractory-lined, insulated reactor furnace 11, and the ore bed 60 is maintained in a fluidised condition by air or other oxygen-containing gas delivered through pipe 20 below apertured plate 17. A pipe 22 for starting or auxiliary fuel, thermocouples 30—32 and pressure-measuring taps 33, 34, are provided. The roasted ore escapes through conduit 25 and the gases through pipe 28 to a cyclone separator. The temperature may be controlled by the use of excess air, by employing comparatively wet ore or by injecting water or another vaporisable, non-combustible liquid into the fluidised bed, or by using auxiliary fuel.—645,977, *W. W. Triggs* (*Dorr Co.*).

Polymerisation process

Articles, particularly sheets, of polymeric materials having at least one smooth surface are produced by causing a liquid or paste containing one or more compounds having the group $CH_2 = C<$ to flow so that it forms a smooth upper surface under gravity. This is then subjected to the polymerising action of heat, light and/or a catalyst when beneath an adjacent surface heated to a temperature sufficient to prevent condensation of any compound volatilised from the liquid or paste. The adjacent surface is preferably heated to a temperature from the boiling point to 20°C. above the boiling point of the highest boiling volatile constituent in the liquid or paste. The space between the liquid or paste and the adjacent heated surface is preferably substantially free from oxygen. The compounds having the group $CH_2 = C<$ are preferably in the liquid state at normal atmospheric temperature and pressure, preferred compounds being methyl methacrylate, styrene, vinyl acetate, diglycol dimethacrylate, allyl methacrylate, diallyl oxalate and the compounds described in Specifications 581,251, 588,660, 595,881, 596,467, 599,837, 606,716 and 606,717. Plasticisers such as tricresyl phosphate or dibutyl phthalate, fillers, reinforcing materials such as fabrics, dyes and pigments may be incorporated.

The process may be carried out by causing the liquid or paste to flow on to a moving surface which carries it through a polymerisation zone. This moving surface may be made of metal and supported on a liquid or may be the upper surface of a liquid which will not mix with the liquid or paste, and which may be spread on the upper surface of a metal plate or band.

In a preferred process a continuous flexible metal band 1 is supported and driven by drums 2, 3, which also drive gaskets 4 to provide side-walls for the trough in which polymerisation takes place. A hollow chamber formed by trough 6



with a cover has slots 9, 10, one at each end, through which pass the metal band 1 and the gaskets 4. The metal band is supported on brine delivered to trough 6 through pipe 11 and flowing out through slot 10 and dropping into a funnel 12. The cover over trough 6 is heated by means of an electrical heater 14 so that its inner surface is raised to a temperature about 10°C. above the boiling point of the highest boiling volatile constituent of the liquid or paste, *e.g.* to a temperature of 110°C. when polymerising methyl methacrylate. Liquid or paste to be cast passes from storage tank 15 through slot 9 at such a rate that a substantially constant level thereof is maintained on the band 1. Heat activation may be effected by inserting infra-red lamps inside the hollow chamber above the liquid or paste being cast and, in the case of photo-polymerisation, suitable sources of radiation may be installed inside or outside this chamber. The rate of polymerisation and the rate of movement of the band 1 are adjusted so that polymerisation is complete before slot 10 is reached. Specifications 491,739, 622,374 and 626,155 also are referred to.—641,284, *A. Burness, E. G. Williams and Imperial Chemical Industries Ltd.*

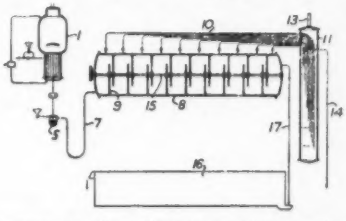
Anti-corrosive coatings

Amine, *e.g.* diethanolamine, methylamine, diethylamine, triethanolamine or morpholine, salts or ammonium salts of nitrophenol, nitrocresol or nitronaphthol are added in a minor amount, *e.g.* 0.2 to 2%, as anti-corrosive ingredients in paints or varnishes comprising binders, *e.g.* nitrocellulose, coumarone, urea-formaldehyde, phenol-aldehyde or alkyd resins, in an organic solvent, *e.g.* benzene, alcohols and their esters, chlorinated hydrocarbons, acetone, cyclohexane or silicanes. Drying agents, plasticisers, pigments and organic dyes, may also be present. The salts may be dissolved directly in the paint or in a diluting agent, or mechanically dispersed in a finely divided state.—640,729, *A/B. Hassle Apotekare Paul Nordstroms Fabriker.*

Sugar crystallisation

Sugar solutions are crystallised by submitting the solution, saturated at a high temperature and charged with seed crystals, to several stages of increasing vacuum. By this means it is continuously evaporated without supply of heat. The differences in vacuum between succeeding stages are so maintained that the differences progressively increase towards the delivery end of the process. The heat of evaporation is withdrawn from the mass itself, and the rate of cooling is such that a uniform growth of crystals is secured.

Saturated sugar solution from steam-heated evaporator 1 is mixed with seed grain in vessel 5, and the mass is then supplied through pipe 7 to crystallising vessel 8. This crystalliser is divided into compartments by partitions 9, and each compartment has a vapour take-off pipe 10 which terminates below water in a vessel 11 provided with a water overflow 14. The immersed lengths of successive pipes 10



decrease in the direction of flow of the solution, and the difference in length between the immersed portions of adjacent pipes increases in the same direction. Vessel 11 is connected by pipe 13 to a condenser maintained at sub-atmospheric pressure. As the mass passes through the compartments of crystalliser 8, evaporation takes place at lower and lower temperatures, and the crystals grow uniformly. The mass is stirred by members attached to shaft 15 during crystallisation. The crystallised mass discharged from the last compartment through pipe 17 is either sent to cooler 16, where the growth of crystals is continued, or it is added as core grains to another sugar solution for obtaining a coarse-grained product.—651,410, *N. V. Werkspoor.*

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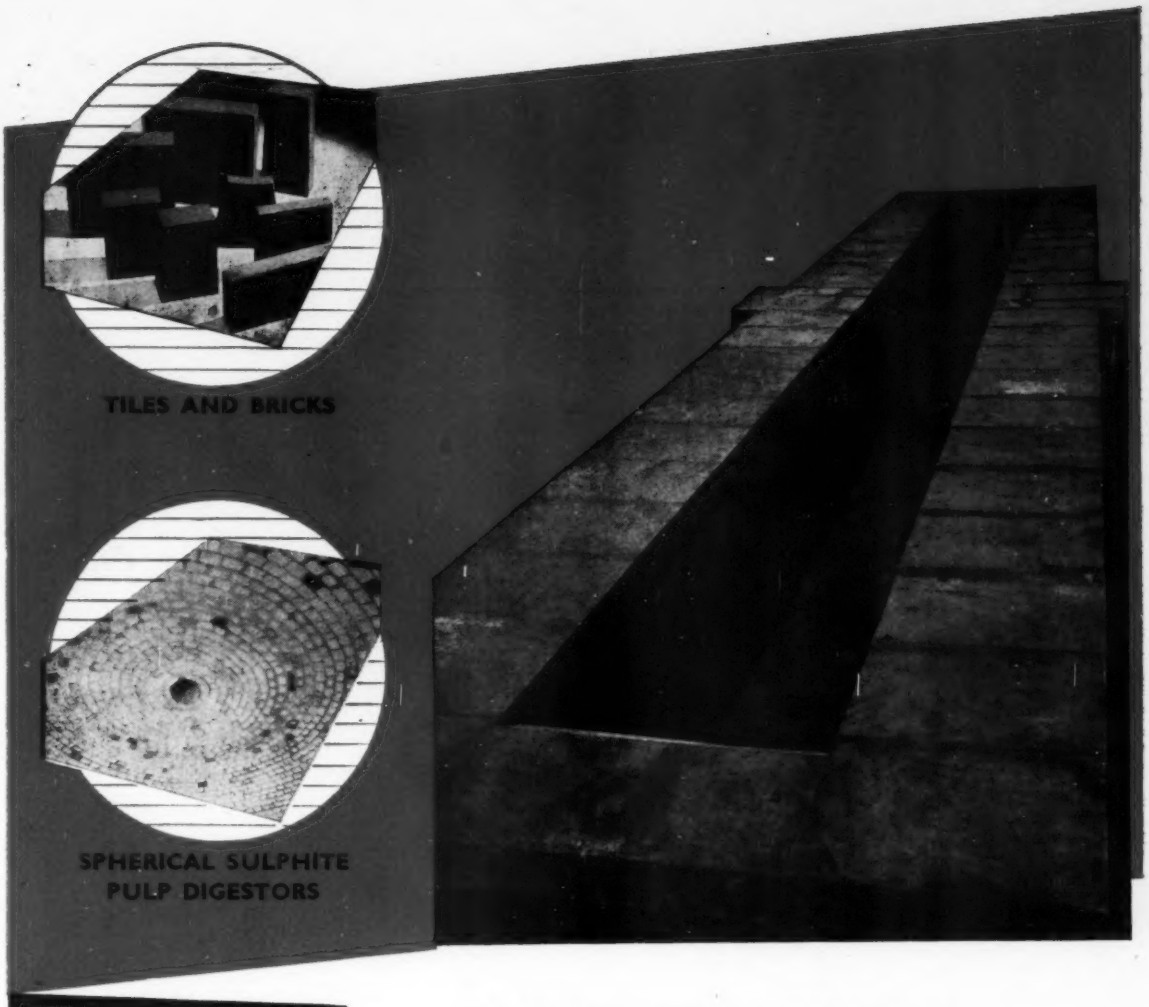

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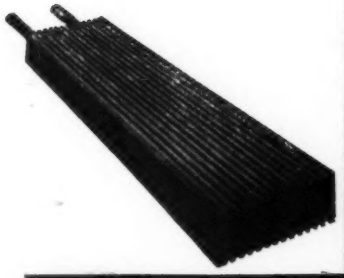

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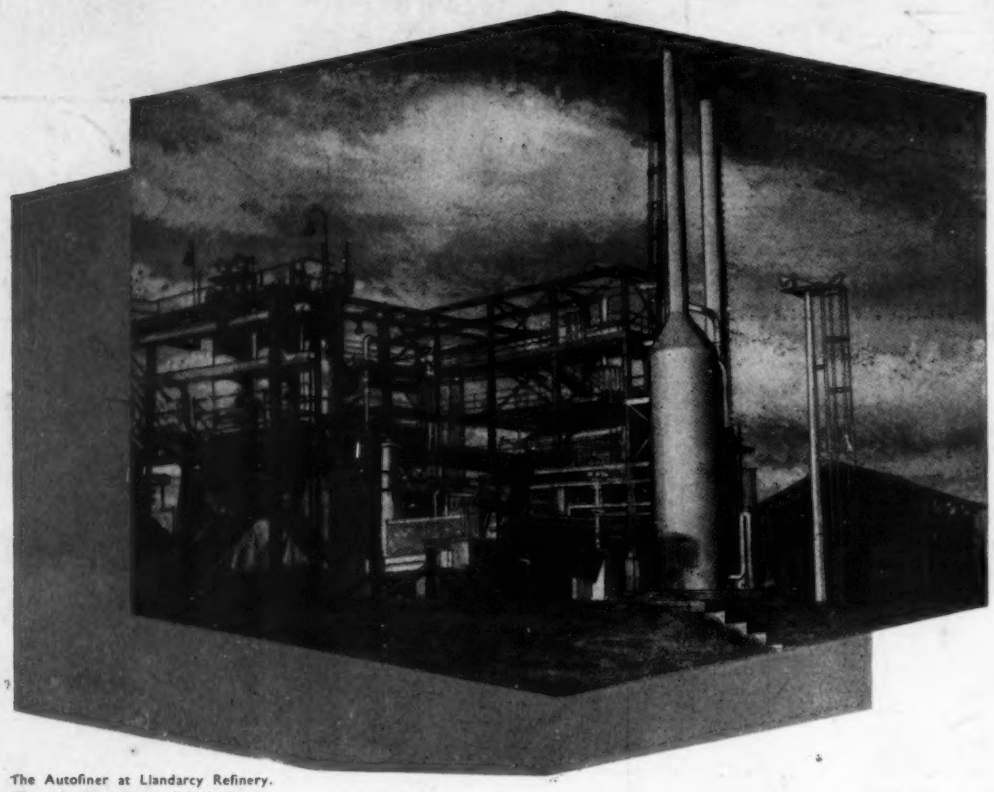

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